Presented by

.....

.....193

22101927992

ROYAL SANITARY INSTITUTE

LIBRARY REGULATIONS

1. Books may be borrowed by Fellows, Members and Associates personally or by a messenger producing a written order. The person to whom books are delivered shall sign a receipt for them in a book provided for that purpose.

2. Books may be sent through the post, or by some equivalent means of carriage, upon a written order. All charges of carriage to the Institute shall be defrayed by the borrower.

3. A borrower may not have more than three volumes in his possession at one time.

4. A borrower will be considered liable for the value of any book lost or damaged while on loan to him, and if it be a separate volume, for the value of the whole work rendered imperfect.
Marking or writing in the volumes is not permitted, and borrowers are requested to call attention to damage of this character.

5. Books may be retained for 28 days. Periodicals may be retained for 14 days. Applications for extension of the loan period must be made in writing before its expiry. No book may be kept longer than 3 months.
New books will not be lent until after the expiration of one month from the date of their having been received by the Institute. The current number of a periodical may not be borrowed.

6. Borrowers retaining books longer than the time specified, and neglecting to return them when demanded, forfeit the right to borrow books until the volume or volumes be returned, and for such further time as may be ordered.
Any borrower failing to comply with a request for the return of a book shall be considered liable for the cost of replacing the book, and the Council may, after giving due notice to him, order the book to be replaced at his expense.
No volume may be reissued to the same borrower until at least seven days have elapsed after its return, neither may it be transferred by one borrower to another.

7. Books may not be taken or sent out of the United Kingdom.

8. Volumes returned through the post must be securely packed in a box, or otherwise protected.

Parcels should be addressed:
THE ROYAL SANITARY INSTITUTE,
90, BUCKINGHAM PALACE ROAD,
LONDON, S.W.1.

THE ROYAL SANITARY INSTITUTE LIBRARY
90, Buckingham Palace Road, London, S.W.I.

Class No. EC/21c Acc. No. .....

This book is returnable **on or before the last date Marked below.**

1 JUN	
1 JUL 1946	
4 APR 1947	

ROYAL COMMISSION ON SEWAGE DISPOSAL.

SUPPLEMENTARY VOLUMES PRESENTED WITH THE

FOURTH REPORT

OF

THE COMMISSIONERS

APPOINTED IN 1898

TO INQUIRE AND REPORT WHAT METHODS OF

TREATING AND DISPOSING OF SEWAGE

(INCLUDING ANY LIQUID FROM ANY FACTORY OR MANUFACTURING PROCESS)

MAY PROPERLY BE ADOPTED.

VOLUME IV.

REPORTS TO THE COMMISSION BY DR. MCGOWAN, DR. HOUSTON, AND MR. KERSHAW ON LAND-TREATMENT OF SEWAGE.

PART I.—GENERAL REPORT.

Presented to both Houses of Parliament by Command of His Majesty.

LONDON:
PRINTED FOR HIS MAJESTY'S STATIONERY OFFICE,
BY WYMAN AND SONS, LIMITED, FETTER LANE, E.C.

And to be purchased, either directly or through any Bookseller, from
EYRE AND SPOTTISWOODE, EAST HARDING STREET, FLEET STREET, E.C.; and
32, ABINGDON STREET, WESTMINSTER, S.W.; or
OLIVER AND BOYD, EDINBURGH; or
E. PONSONBY, 116, GRAFTON STREET, DUBLIN.

1904.

[Cd. 1886.]

Presented by

Purchased

October 1908

WELLCOME INSTITUTE LIBRARY
Coll. welMOmec
Call
No. WA 785
1902
G78r

REPORTS

TO THE

ROYAL COMMISSION ON SEWAGE DISPOSAL

ON

LAND TREATMENT OF SEWAGE.

PART I.

GENERAL REPORT

BY

DR. G. McGOWAN, DR. A. C. HOUSTON, AND MR. G. B. KERSHAW.

NOTE.—These Reports to the Commission on Land Treatment of Sewage are published in four parts, viz. :—

Part I.—General Report by Dr. G. McGowan, Dr. A. C. Houston, and Mr. G. B. Kershaw.

Part II.—Chemical Report by Dr. G. McGowan.

Part III.—Bacteriological Report by Dr. A. C. Houston.

Part IV.—Engineering and Practical Report by Mr. G. B. Kershaw.

6225. 1500.—Wt. 5470. 9/04. Wy. & S.

EXTRACT FROM THE FOURTH REPORT OF THE ROYAL COMMISSION ON SEWAGE DISPOSAL. (1904. Cd. 1883).

28th December 1903.

"We have considered it desirable to publish, at this stage, the results and information which have been obtained by our own officers in regard to land treatment of sewage and methods of analysis, but we shall defer reporting on these matters until our investigations, which are now in progress, in regard to other methods of sewage treatment, are completed." (Paragraph 117, page xliii.)

ROYAL COMMISSION ON SEWAGE DISPOSAL.

REPORT TO THE COMMISSION ON LAND TREATMENT OF SEWAGE.

I.—GENERAL REPORT.

The following "General" Report on Land Treatment of Sewage contains a summarised statement of the various results of which the details are to be found respectively in the Chemical, Bacteriological, and Engineering Reports on the subject.

CONTENTS.

		PAGE.
Section	I.—Introductory and General Scope of Enquiry	5
Section	II.—Particulars relating to each of the eight Sewage Farms kept under detailed observation	8
Section	III.—Short Summary of the work done by the Rivers Pollution Commission of 1868 on the Land Treatment of Sewage	33
Section	IV.—Practical and Meteorological Observations, Collection of Samples and Notes relating to the routine work carried out during the visits to the several Sewage Farms	37
Section	V.—Summary of the Chemical Results and Conclusions	45
Section	VI.—Summary of the Bacteriological Results and Conclusions	67
Section	VII.—Comparison between the Chemical and Bacteriological results	79
Section	VIII.—Engineering and Practical Conclusions	103
Section	IX.—General Conclusions	105
Appendix	A.—Management of Sewage Farms	115

SECTION I.

Introductory and General Scope of Enquiry.

Having been instructed by the Commission to enquire into the subject of the land treatment of sewage, we proceeded to visit a large number of sewage farms throughout the country. During our inspection of these farms we paid attention to the following points, among others, namely :—

(I.) The general character of the soil and subsoil, and whether the original surface soil had been "lightened" by ashes or other substances, or "treated" with chalk.

(II.) Whether or not the land was drained, and, if so, the nature of the drainage arrangements.

(III.) Whether the land was cropped, and if so, the nature of the crops.

(IV.) (*a*) Whether the whole of the crude sewage (liquid and solid together); or

(*b*) The settled sewage after subsidence in tanks; or

(*c*) The sewage, after chemical precipitation and settling; or

(*d*) The effluent from some other artificial process of sewage treatment was being run on to the land.

(V.) Whether surface irrigation or filtration was adopted.

(VI.) Whether the sewage was a domestic sewage or a mixed sewage.

If the latter, the nature and amount of trade refuse gaining access to the sewers.

(VII.) The provisions made for "treating" storm water on the land, and its bulk in relation to the dry weather flow of sewage.

(VIII.) The amount of subsoil water gaining access to the sewerage system, and also the proportion of subsoil water which reached the effluent drains on the sewage farm.

(IX.) The number of years during which the farm had been in existence.

(X.) Whether the whole of the soil was really in active operation, or whether any portion of the sewage escaped, in a practically unaltered condition, through cracks or borings into the drains.

(XI.) Whether the different effluents met and mixed together on the farm and discharged in a common channel, or escaped separately into a watercourse.

(XII.) Whether the effluents were being discharged into a drinking water or into a non-drinking water stream.

(XIII.) Other points to be considered were :—

Whether the soil was fresh or showed signs of being overdone; whether the farm was well managed and supervised; whether it was worked mainly with a view to producing a good effluent or to obtaining a profit from the crops; and whether the sludge was disposed of on the land of the farm, and, if so, how and with what results.

(XIV.) Further, notes were made with regard to the situation of the farm, the total acreage, the total irrigable area, the average area irrigated at one time, the population draining to the farm, the population per acre irrigated, the number of gallons of sewage per head per day, the dry weather flow of sewage per twenty-four hours, the number of gallons of sewage treated per acre per twenty-four hours, separate or combined system, cost of treatment, etc.

The results of our inspection of twenty-nine sewage farms, when considered in relation to the above factors and their manifold and complex combinations, led us to conclude that it would be best to attack the subject in a broad and general way.* With this object in view, we in the first place limited our observations to the treatment on land either of *domestic sewage*, or of sewage containing no excessive amount of trade effluents. Secondly, we differentiated farms according to the nature of their soils. Thirdly, we confined our investigation of the different kinds of soil to seven varieties fairly representative of those found on different sewage farms, and in use, or likely to be used, for the purification of sewage, namely, sand, sand and gravel, light loam, heavy loam, clay, peat, and chalk.

Lastly, we chose for detailed observation sewage farms representative of the above kinds of soil, namely:—

Aldershot Camp (sand), Croydon (Beddington) (gravelly loam), Nottingham and Cambridge (light loam), Rugby (High Level farm) (heavy loam), South Norwood and Leicester (clay), and Altrincham (peaty soil and sand). Luton, a typical instance of a chalk sewage farm, was also kept to some extent under observation. We also obtained some samples from the sewage farms of Worsley (partly peat, partly sand and gravel), Hemsworth (clayey soil), Derby County Asylum (stiff soil overlying red clay), Lindfield (clayey soil), Sandhurst (sandy soil), and Woking (Bagshot sand).

Birmingham sewage farm is an exceptionally interesting one, treating as it does septic tank liquor; but its great size, the differences in the nature of the soil over the farm, and the important consideration of time prevented us from including it in this scheme of work.

In the Bacteriological and Chemical Reports attention is drawn to the valuable assistance which has been rendered in the course of this investigation by our colleague Dr. Gordon, and later by Miss Power and Miss Hartley in the bacteriological work; and by Mr. R. B. Floris, A.I.C., Mr. R. S. Finlow, B.Sc., Miss Chick, B.Sc., and later by Mr. E. H. Richards, B.Sc., in the chemical work. We are also much indebted to our colleague, Mr. Colin C. Frye, for many valuable suggestions.

We desire to acknowledge our great indebtedness to the various officials connected with the management of these farms for much useful information and willing help. In particular our thanks are due to those connected with the farms kept under detailed observation.

---

* It may be pointed out here that many of the factors about to be dealt with are incapable of being weighed or measured as regards their bearing on the subject as a whole. This being the case, it may be said at the outset that the subsequent interpretation of our facts, in their relation to these variable circumstances, cannot be expected to be other than of the nature of a broad generalisation.

SECTION II.

Particulars relating to each of the Eight Sewage Farms kept under Detailed Observation.

The following is a tabular statement of the chief points of interest in connection with each of the eight sewage farms kept under detailed observation. In this table the farms are arranged in alphabetical order :—

	Aldershot Camp.	Altrincham (Cheshire).	Cambridge.	Beddington (Croydon).	Leicester.	South Norwood (Croydon).	Nottingham.	Rugby.
1. Situation of farm - - - -	Ashvale, near camps.	Near Carrington Moss, two miles from Altrincham.	Three miles from Cambridge.	Three miles from Croydon.	Two miles from Leicester.	Near South Norwood.	Stoke Bardolph, five miles from Nottingham.	New Bilton, one mile from Rugby.
2. Total acreage of farm - - -	138·5 acres.	75·5 acres.	102·5 acres.	673·5 acres.	1,699 acres.	191 acres.	907 acres (1900).	40 acres.
3. Total irrigable area - - -	120·5 acres.	35 acres.	74 acres.	420 acres.	1,350 acres.	152 acres.	651 acres (1900).	35 acres.
4. Average area irrigated at one time	About 40 acres.	17·5 acres.	18·5 acres.	About 70 acres.	337 acres.	50 acres.	300 acres.	7 acres.
5. Population draining to farm - -	20,000	18,000	50,000	100,000	197,000	21,000	258,584	6,000
6. Population per acre irrigated -	166	514	675	238	146	138	397	171
7. Gallons of sewage per head per day	50	44·4	45	40	36·8	28·5	27	50
8. Dry weather flow of sewage per 24 hours.	1,000,000 gallons.	800,000 gallons.	2,250,000 gallons.	4,000,000 gallons.	7,250,000 gallons.	600,000 gallons.	7,000,000 gallons.	300,000 gallons.
9. Gallons of sewage (exclusive of storm water) treated per acre per 24 hours.	25,000	46,000	121,600	57,100	21,500	12,000	23,300	42,800
10. Gallons of sewage treated per acre per 24 hours, on the assumption that each acre of the irrigable area is under sewage all the time.*	8,300	23,000	30,400	9,500	5,370	4,000	10,750	8,500
11. Character of the sewage - -	Purely domestic.	Domestic.	Mainly domestic. Some brewery refuse.	Almost purely domestic.	$\frac{3}{4}$ Domestic; $\frac{1}{4}$ trade refuse.	Purely domestic.	$\frac{4}{7}$ Domestic; $\frac{3}{7}$ trade refuse.	Mainly domestic.
12. Method of treatment - - -	Screening, settling tanks and land filtration.	Settling tank and land filtration.	Screening and settling tank and land filtration.	Screening, surface irrigation and filtration.	Screening, settling tanks, surface irrigation and filtration combined.	Screening, settling tanks and surface irrigation (with a little filtration).	Screening (partial) and land filtration.	Screening, settling tanks, surface irrigation and filtration combined.
13. General character of the soil and sub-soil.	Sand.	Peaty soil lying upon sand and gravel.	Sandy loam overlying gravel and sand.	Gravelly loam over gravel and sand.	Stiff clayey soil overlying dense clay.	A clay soil resting on London clay.	Light sandy loam and gravel overlying gravel and sand.	Heavy loam overlying stiff clay.
14. Separate or combined sewerage system.	Separate.	Combined.	Partially separate.	Partially separate.	Partially separate.	Partially separate.	Combined.	Partially separate.
15. The final effluent is discharged into :—	River Blackwater.	Sinderland Brook.	River Cam.	River Wandle.	Anstey Brook (flowing into River Soar).	Chaffinch Beck.	River Trent.	River Avon.
16. Number of years farm in operation before 1900.	36 years.	30 years.	5 years (systematic) working.	39 years.	9 years.	36 years.	19½ years.	33 years.

Samples were also obtained from Luton, Derby County Asylum, Hemsworth, Sandhurst, Lindfield, Woking and Worsley Sewage Farms.

* *Note.*—The object of making this assumption—which would of course be entirely out of the question in practice—was to facilitate the comparison of the different farms with regard to the amounts, etc., of sewage treated on them.

SECTION II.

PARTICULARS RELATING TO EACH OF THE EIGHT SEWAGE FARMS KEPT UNDER DETAILED OBSERVATION (*see* FOREGOING TABLE AND ALSO DIAGRAM 1.)*

1. *Situation of Farm.*

In the following statement the farms are arranged in the inverse order of their proximity to the town sewered :—

Nottingham	about 5 miles.
Beddington, Cambridge	about 3 miles.
Altrincham	about 2 miles.
Rugby	about 1 mile.
Aldershot Camp, South Norwood	less than 1 mile.

The advantages on the one hand and the disadvantages on the other of having a sewage farm at some considerable distance from the town sewered, may be summed up as follows :—

Advantages.	*Disadvantages.*
The whole of the sewage may be run on to the land in a disintegrated and partially decomposed condition, without any preliminary treatment. In special cases *rough* screening and settlement of the grit may have to be resorted to. There are sentimental, if not also health, considerations for treating sewage in thinly-populated districts. The land is likely to be cheaper in sparsely-populated areas. There is less likelihood of difficulty in extending the area of the farm to keep pace with a growing population.	The solid fæcal matter which, taken by itself, has a definite manurial value and would otherwise be easily manipulated, and the cellulose matters, which have a clogging tendency, pass on to the land with the watery part of the sewage, whereas in the case of *fresh* sewage it is not difficult to screen out much of the solid fæcal matter and a certain amount of the paper, and to dispose of it to farmers or to make use of it on the farm itself.
The longer the outfall sewer, the more likely is the sewage to have a uniform composition and an equable flow.	If settling tanks and precipitation methods are in operation, the sludge is apt to be of small market value and is not readily disposed of. The longer the outfall sewer, (1) the greater the initial cost; (2) the greater the cost for repairs, and (3) the larger the amount of subsoil water likely to gain access to the sewer, which, so far as bulk of liquid to be disposed of is concerned, is a positive disadvantage.

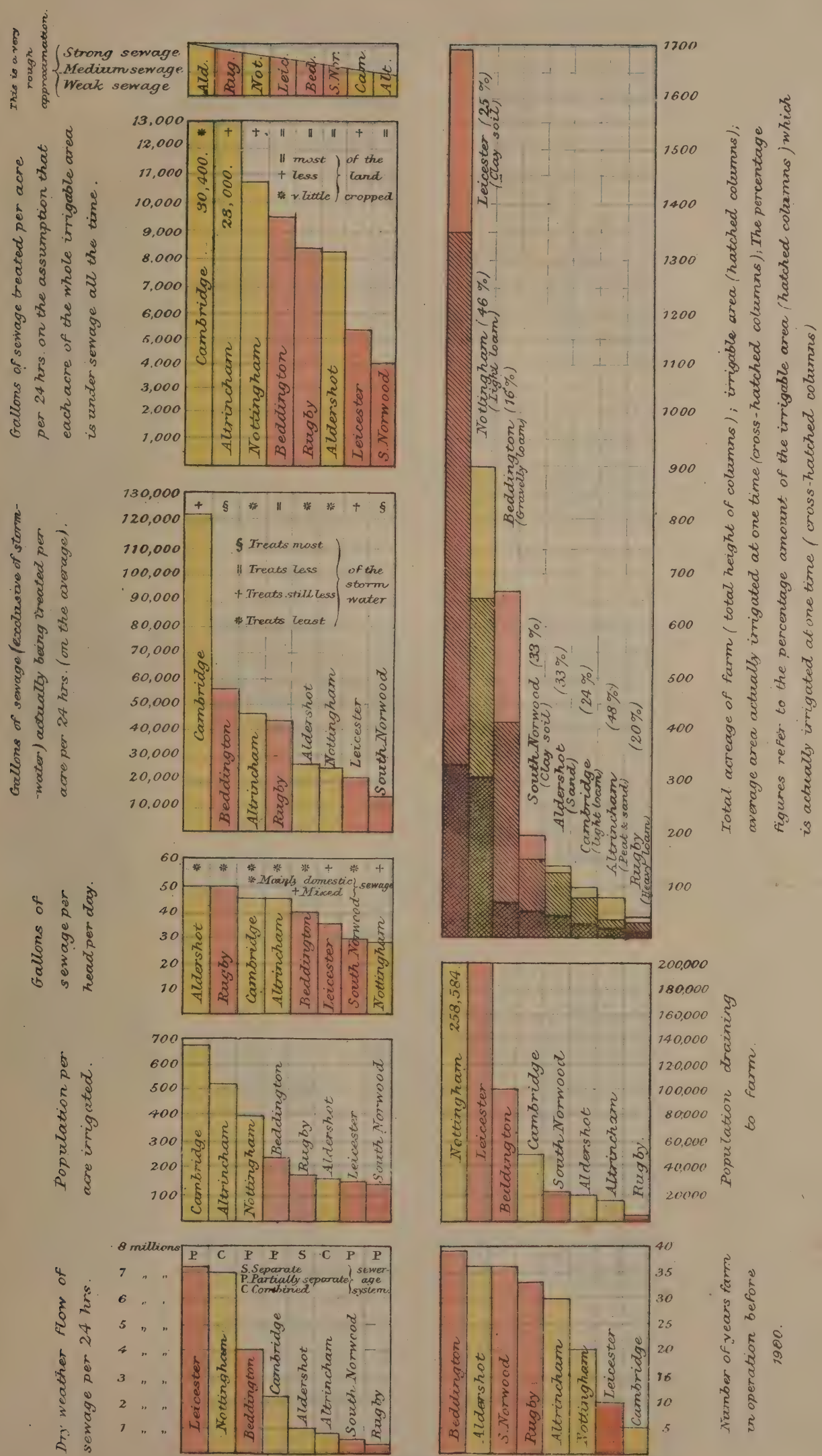
The distance of a sewage farm from the town sewered is usually governed by practical considerations; for example, by the suitability of the soil, the necessity for avoiding pumping, if possible, etc.

The subject is one concerning which it is obviously impossible to pronounce any decided opinion, but in general cases there would, on the whole, seem to be a clear advantage in having a sewage farm at a considerable distance from the town sewered.

* We would draw special attention to Diagram 1, which illustrates the chief particulars of note in connection with each of the eight sewage farms kept under detailed observation.

Diagram 1.

Diagram illustrating the chief particulars of note in connection with each of the eight sewage farms kept under detailed observation.



N.B. The yellow colouring refers to the filtration farms; the red colouring to the combined surface irrigation & filtration farms.

Weller & Graham Ltd Litho. London

Diagram 2.

Diagram showing (1) in percentages of the Total Acreage (a) the Surplus Acreage and (b) the Total Irrigable area; and (2) in percentages of the Total Irrigable area (a) the "Resting" and (b) the "Working" areas at each of the Eight Sewage Farms kept under detailed observation.

The yellow colouring refers to the Filtration Farms; the red colouring to the combined surface Irrigation and Filtration Farms.

3311.1.03

Walter & Grahams Lm Litho. London.

2. *Total Acreage of Farm.*

(*See* Diagrams 1 and 2.)

The following is the order of the farms arranged according to their size :—

	Total Acreage.	Surplus Acreage (*i.e.* acreage in excess of the total irrigable area.)
Leicester - - - - -	1,699	349 (about 20 °/₀ of the total acreage.)
Nottingham - - - -	907	256 („ 28 „ „)
Beddington - - - - -	673	253 („ 37 „ „)
South Norwood - - - -	191	39 („ 20 „ „)
Aldershot Camp - - - -	138	18 („ 13 „ „)
Cambridge - - - - -	102	28 („ 27 „ „)
Altrincham - - - - -	75	40 („ 53 „ „)
Rugby (High level) - - -	40	5 („ 12 „ „)

It must, of course, be borne in mind that the volume and character of the sewage, and the nature and effective purifying area of the soil varied greatly at the several farms.

It is obvious that the total acreage of a farm must be relatively much greater where the sewage is purified by surface irrigation than where the method of deep filtration is employed.

Apart from the more important question of the volume of sewage which is being treated per acre of the irrigable area, the total acreage of a sewage farm is not unimportant. A sewage farm may be so large as to be difficult to manage, or so small as to be economically a failure. None of the above sewage farms, however, come under either of those categories.

There is a wide distinction between the total acreage of a farm and the total irrigable area. The total irrigable area is that portion of the whole farm laid out for irrigation* purposes, and which is actually irrigated at one time or another in the course of the year.

It must not be supposed that the extent of the surplus area (*i.e.*, acreage in excess of the total irrigable area) is a matter of minor concern. It may, on the contrary, be of considerable importance, especially if the land under sewage is cropped, because, as cereals are practically speaking inadmissible on the irrigable area, the crops ought to be of a kind (*e.g.*, rye-grass) capable of being heavily sewaged and readily disposed of when gathered. There is frequently an economic advantage in using the surplus area as a dairy farm, and feeding the stock with the produce from the irrigable area, especially in those cases where there is difficulty in disposing of crops. This, however, involves additional capital expenditure, the investment being of a somewhat speculative character. Further, if any portion of the surplus area is capable of being inexpensively laid out for irrigation purposes (this will depend on many factors, *e.g.*, contour of the land, etc.), provision exists for further extension if required.

It will be noted, as shown above, that the percentage surplus area varies considerably at the different farms. When surface irrigation is adopted, a proportionately larger surplus area is naturally desirable. Arranged according to the percentage surplus area, the farms fall into the following order :— Altrincham, 53 per cent. ; Beddington, 37 per cent. ; Nottingham and Cambridge, about 28 per cent. ; Leicester and South Norwood, about 20 per cent. ; Aldershot Camp and Rugby, about 13 per cent.

* *The term "irrigation" in this report is applied in the wide sense,* i.e., *to the land treatment of sewage, irrespective of whether the method employed is that of "surface irrigation" or "filtration."*

The surplus acreage may often be conveniently used for special purposes, *e.g.*, turning out of stock, sludge disposal, etc. Further, if it should be impossible to obtain new land for extension purposes, it is always possible either (1) by gravitation, or (2) by pumping (necessarily an expensive method) to utilise the surplus area.

It is impossible to lay down any rule as regards what the ratio of the surplus to the total acreage should be. Each case must be judged on its own merits and in relation to the local conditions. But we are of opinion that, generally speaking, a large surplus acreage is advisable, and it is naturally of great advantage to have this surplus land so circumstanced as to admit of the possibility of its being inexpensively laid out for irrigation purposes, if required.

It is assumed, of course, that the total irrigable area is of suitable size in proportion to the volume of sewage to be treated.

A sewage farm with an irrigable area too small in proportion to the volume of sewage to be dealt with is obviously to be condemned, no matter how large the surplus acreage may be.

3. *Total Irrigable Area.*

(*See* diagrams 1 and 2.)

The farms may be arranged according to the extent of the total irrigable area as follows :—

	Total irrigable area (acres).	Total acreage.	Percentage proportion of the total acreage of the farm available for irrigation purposes.
Leicester - - - - -	1,350	1,699	About 79 per cent.
Nottingham - - - -	651	907	„ 71 „ „
Beddington - - - -	420	673	„ 62 „ „
South Norwood - - - -	152	191	„ 79 „ „
Aldershot Camp - - -	120	138	„ 87 „ „
Cambridge - - - - -	74	102	„ 72 „ „
Altrincham - - - -	35	75	„ 46 „ „
Rugby - - - -	35	40	„ 87 „ „

The terms total acreage, total irrigable area, and surplus acreage have been explained already. It may now be pointed out that there is a fundamental difference between the total irrigable area of a farm and the average area irrigated at one time. The latter, of course, is that portion of the total area of land laid out for irrigation purposes which, on the average, is being at one time actually used for sewage purification.

The percentage of the total acreage of farm available for irrigation purposes is shown in the above table. The following is the order of the farms arranged according to the percentage proportion (from the less to the greater) of the total acreage available for irrigation purposes :—Altrincham, 46 per cent. ; Beddington, 62 per cent. ; Nottingham, 71 per cent. ; Cambridge, 72 per cent. ; Leicester, 79 per cent. ; South Norwood, 79 per cent. ; Aldershot Camp, 87 per cent. ; Rugby, 87 per cent. These figures are of course the complement of those given under "Surplus Acreage" of farms, but they are appended here for the sake of completeness. The larger the total irrigable area, the greater is likely to be the working cost. In this respect surface irrigation methods, which naturally require a proportionately greater total irrigable area, compare unfavourably with filtration processes : this additional cost, however, is to some extent counterbalanced by the return on crops. An important feature is to have the total irrigable area

largely in excess of that portion of the irrigable area which is required efficiently to purify the normal flow of sewage at one time. In other words, the "resting" irrigable area should be considerable, both in order to enable the soil to recover its full purifying power under the ordinary conditions of working, and also to allow for emergencies occasioned by a suddenly increased flow. This question of surplus or "resting" irrigable acreage is apt to be dominated by farming considerations, and not always by the endeavour to obtain the best results possible in the way of purification of the sewage.

It may thus happen that, to save a backward crop, a totally inadequate portion of the total irrigable area is heavily and continuously sewaged, to the great detriment of the land itself and also to the quality of the effluent that is being produced. It is one thing to be in favour of a large surplus irrigable area and, on economic and other grounds, also to advocate cropping the land, and quite another thing to regard the proper purification of the sewage as secondary to the farming operations. The surplus irrigable area should be regarded primarily as a means of resting land recently sewaged, and quite secondarily as a suitable soil for the remunerative growth of crops. With good management, however, the larger the surplus irrigable area the better not only is the purification likely to be, but also, within certain limits, the prospect of profit. Here again, it is assumed that the area actually under sewage at one time is sufficiently large to purify adequately the amount of sewage that has to be dealt with.

4. *Average Area Irrigated at One Time.*

(*See* diagrams 1 and 2.)

Arranged according to the average area irrigated at one time, the farms come in the following order :—

	Average area irrigated at one time.	Total irrigable area.	Percentage of the total irrigable area actually irrigated at one time.
	Acres.	Acres.	
Leicester - - - -	337	1,350	About 25 per cent.
Nottingham - - - -	300	651	„ 46 „ „
Beddington - - - -	70	420	„ 16 „ „
South Norwood - - .	50	152	„ 33 „ „
Aldershot Camp - - -	40	120	„ 33 „ „
Cambridge - - - -	18	74	„ 24 „ „
Altrincham - - - -	17	35	„ 48 „ „
Rugby - - - - - .	7	35	„ 20 „ „

These figures are of great importance because, when considered in conjunction with the dry weather flow of the sewage, they shew the volume of sewage actually treated per acre. The area is naturally greater in the case of the surface irrigation farms. The proportion of the total irrigable area on the average under sewage at one time must obviously have an important bearing on the results obtained. This point raises the very complex question of intermittency. The more porous a soil, the more sewage it is usually called upon to treat per acre; but whether or not it is better heavily to sewage a limited area with long intervals of rest, or lightly to sewage a larger

area with shorter periods of rest, is a moot point. It would be desirable that this subject should be studied in a systematic manner.

Nor do we know, with a given ratio between the "working" area and total irrigable area, whether it is better to have long or short periods of working and resting. For example, with a ratio of one of "working" area to two of total irrigable area, is it better to sewage the "working" area on alternate days or for alternate weeks, or alternate months? In practice great variations occur at the different sewage farms, but at each particular farm the variations are not usually considerable, except when large volumes of storm water have to be dealt with.

It will be noted that the percentage of the total irrigable area actually sewaged at one time varied considerably at the several farms. The order (from the greater to the less) is as follows:—Altrincham, 48 per cent.; Nottingham, 46 per cent.; Aldershot Camp, 33 per cent.; South Norwood, 33 per cent.; Cambridge, 24 per cent.; Leicester, 25 per cent.; Rugby, 20 per cent.; Beddington, 16 per cent.

5. *Population Draining to Farm.*

(*See* Diagram 1.)

The following is the order of the farms arranged according to the population.

	Population.	Total acreage of farm	Population per acre of the total acreage of the farm.
Nottingham* - -	258,584	907	285
Leicester* - - -	197,000	1699	116
Beddington - -	100,000	673	148
Cambridge - - -	50,000	102	490
South Norwood - -	21,000	191	110
Aldershot Camp - -	20,000	138	145
Altrincham- - -	18.000	75	240
Rugby - - -	6,000	40	150

It has been shown that the order of the farms is the same in relation to the total acreage, total irrigable area, and average area irrigated at one time. Here it will be noted that the order is not quite the same, Nottingham taking the place of Leicester, and Cambridge preceding both South Norwood and Aldershot Camp. Side by side with the population, we give the total acreage of the farms and the population per acre of this total acreage; but it is obvious that in acquiring land for sewage purification purposes, the calculation should not be one of population to total acreage, but one of population to that portion of the total area which it is proposed to lay out for irrigation purposes. The order of the farms relative to the population per acre of the total area of the farms, is as follows:—Cambridge, 490; Nottingham, 285; Altrincham, 240; Rugby, 150; Beddington, 148; Aldershot Camp, 145; Leicester, 116; South Norwood, 110.

* *See* footnote on next page.

6. *Population per acre irrigated.*

(*See* diagrams 1 and 3.)

This figure is of course arrived at by dividing the population by the acres of land laid out for irrigation purposes. The following is the order of the farms:—

	Population per acre irrigated.		Population above or below the mean.	Population per acre of the total acreage.	Difference between the population per acre of the total acreage, and the population per acre of irrigable land.
Cambridge - -	675	305 (average).	+ 370 (about 121 per cent.)	490	185
Altrincham - -	514		+ 209 („ 68 „)	240	274
*Nottingham - -	397		+ 92 („ 30 „)	285	112
Beddington - -	238		− 67 („ 21 „)	148	90
Rugby - - -	171		−134 („ 43 „)	150	21
Aldershot Camp -	166		−139 („ 45 „)	145	21
*Leicester - - -	146		−159 („ 52 „)	115	31
South Norwood -	138		−167 („ 54 „)	109	29

Here it will be noted that the order of the farms is greatly altered, the filtration farms coming to the front and the surface irrigation farms, generally speaking, falling behind. Nevertheless, as the number of gallons of sewage per head per day is a variable factor, the population per acre irrigated taken by itself may be misleading as a basis for calculating the work done by land. It is true that the greater the dilution of the excremental matter with the water supply and with subsoil water, the less strong is the sewage; but the difficulty of treatment is a question of volume of sewage as well as of strength. As has been pointed out elsewhere, it is easier to treat a larger volume of a weak sewage than a smaller volume of a strong sewage, so as to bring the resulting effluents within the pale of the fixed standards of purity which are adopted in different parts of the country. But, notwithstanding this, the effluent from the stronger sewage, though apparently worse, might on examination yield actually better results than the other, *i.e.*, might contain less organic matter of a readily oxidizable character (cf. Chemical conclusions to this Report; Sub-section on Standards). As a general rule, the poorer the population the less water is used per head.

For purposes of comparison we have given above the population (1) per acre irrigated and, (2) per acre of the total acreage, and the difference between these. It is obvious that, if proportionate surface areas of the *total acreage* of the farms had been available for irrigation purposes, a very different number of persons per acre would have had to be dealt with than was actually the case. For example, Altrincham was treating on a small proportion of its *total acreage* the sewage of a relatively large population.

* With regard to Nottingham and Leicester, as pointed out elsewhere, the excrementa matter of a portion of the population is kept out of the sewers. On the other hand, those two sewages contain considerable quantities of trade refuse.

7. *Gallons of Sewage per head per day.*
(*See* diagrams 1 and 3.)

Arranged according to the number of gallons per head per day, the farms come as under :—

	Gallons of Sewage per head per day.		Gallons above or below the mean of 40 gallons.
Aldershot Camp - - -	50	Average, 40 gallons.	+ 10 (about 25 per cent.)
Rugby - - - - -	50		+ 10 (about 25 per cent.)
Cambridge - - - -	45		+ 5 (about 12·5 per cent.)
Altrincham - - - -	44·4		+ 4·4 (about 11 per cent.)
Beddington - - - -	40		Average number.
Leicester - - - -	36·8		— 3·2 (about 8 per cent.)
South Norwood - - -	28·5		— 11·5 (about 28·7 per cent.)
Nottingham - - - -	27·0		— 13 (about 32·5 per cent.)

It will be noted that the volume of sewage per head at Aldershot was nearly double that at Nottingham (the two extremes).

As previously pointed out, it seems unadvisable to make the population alone the basis for calculating the land required for sewage purification. Because, as is clearly indicated by the above figures, the volume of sewage per head per day varies at the different farms by as much as about 100 per cent., and volume as well as strength of sewage is a matter of great importance. The above marked differences in the volume of sewage per head per day may be accounted for by the differences in :— (1) Water supply; (2) Subsoil water; (3) Manufactories and private sources of water supply. For example, the relative positions of Aldershot Camp and Nottingham are chiefly owing to the very large water supply per head in the former case and the small water supply in the latter (largely due to the great number of tub closets). Rugby is an example of a sewerage system in which a large amount of subsoil water gains access to the sewers, and the same remark applies to Cambridge. Leicester, although the volume of sewage (37 gallons) per head per day is not very large, is an example of a town having a small water supply and a considerable quantity of refuse water from manufactories.

8. *Dry Weather flow of Sewage per* 24 *hours.*
(*See* diagram 1.)

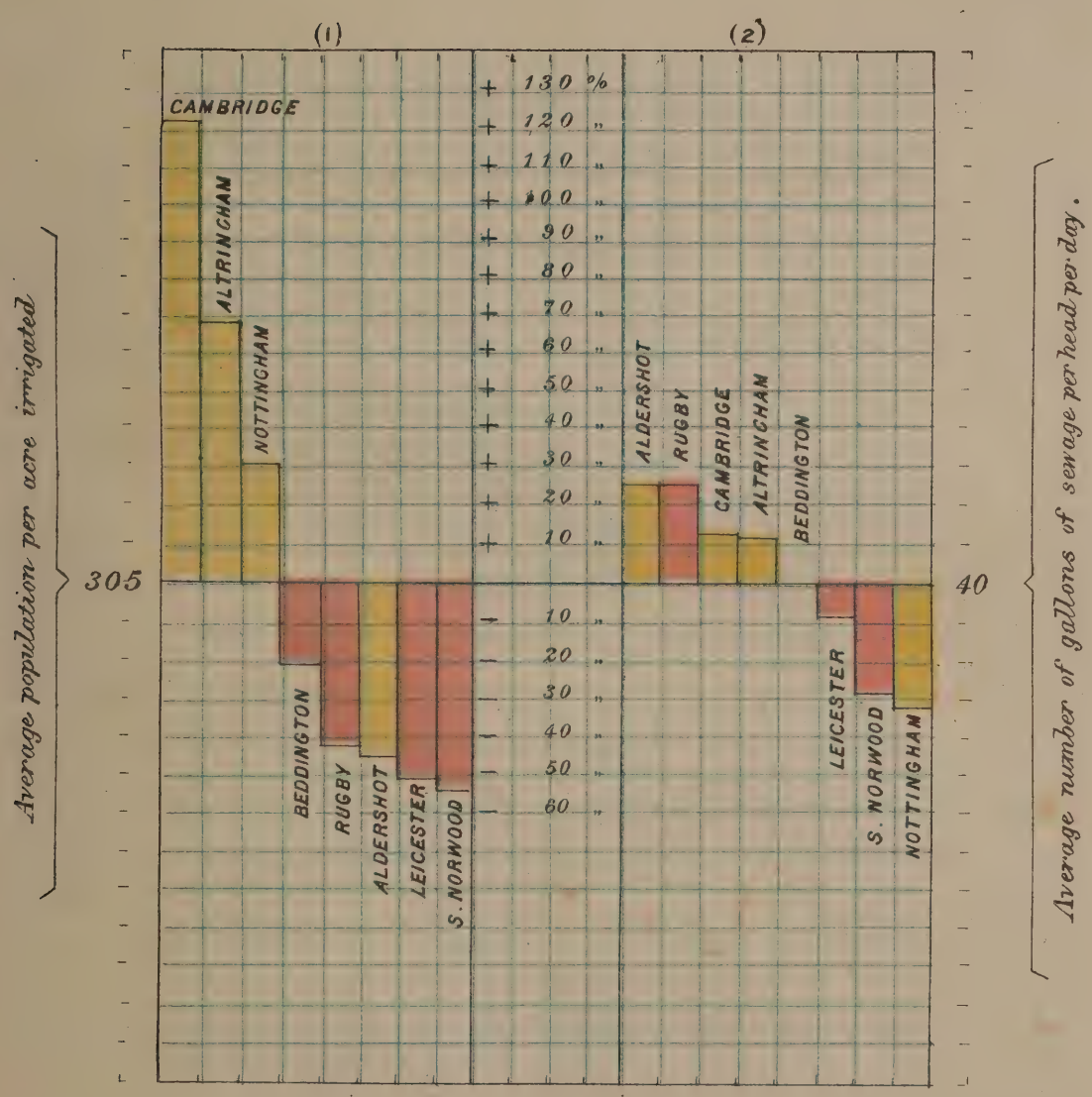
	Dry weather flow per 24 hours (gallons)	Notes as regards storm water.*
Leicester - -	7,250,000	About 2½ times the dry weather flow is treated.
Nottingham - -	7,000,000	Very little storm water is treated.
Beddington (Croydon) - - -	4,000,000	All the storm water which gains access to the sewers is treated on the farm.
Cambridge - -	2,250,000	A small amount only is treated at the farm.
Aldershot Camp -	1,000,000	All the storm water which gains access to the sewers is treated on the farm.†
Altrincham - -	800,000	Very little storm water is treated.
South Norwood -	600,000	All the storm water which gains access to the sewers is treated on the farm.
Rugby - - -	300,000	Nearly all the storm water is treated.

* As regards the relative volumes of storm water treated, Beddington and South Norwood treat most, Rugby less, Cambridge and Leicester still less, and Nottingham, Altrincham and Aldershot Camp least.

† The surface (or storm) water, however, is almost entirely taken off by the separate system, and consequently only a small amount reaches the farm in this case.

Diagram 3.

Percentage above or below the mean of (1) the average population per acre irrigated; and (2) the average number of gallons of sewage per head per day.



The yellow colouring refers to the Filtration Farms; the red colouring to the combined Surface Irrigation and Filtration Farms.

3311. 1 03.

Weller & Graham Ltd Litho. London.

The above figures, divided in each case by the average area irrigated at one time, give the gallons of sewage treated per acre per twenty-four hours.

It is perhaps a point worth noting that, during a portion of each day, and on one day as compared with another, the rate of flow fluctuates to a considerable, even to a marked extent. Managers of sewage farms learn how to deal with the above irregularities of flow because (excepting when trade effluents are sent down in flushes) they usually occur at more or less regular intervals. But when to these fluctuations is superadded the uncertain element of storm water, the difficulties are largely increased, particularly in the case of surface irrigation farms. This is only one of the many conflicting factors which cannot be accurately weighed or estimated, but which, nevertheless, have an important bearing on the land treatment of sewage. Some farms treat nearly the whole, others only an inconsiderable portion of the storm water. Relative to the dry weather flow, the volume of storm water may be large or small. It may tend to occur (a) in occasional but heavy flushes, or (b) more frequently but in less volume at a time.

Beddington (Croydon) and South Norwood are examples of sewage farms which treat the whole of the storm water reaching the sewers, although it must be remembered that the separate system is in use over a portion of the area sewered. The whole question has been treated so fully in the Engineering Report* that it does not seem desirable to enter into further details here.

It must be carefully borne in mind that the number of gallons stated to be treated per acre, etc., is based on the *dry weather flow*, and does not include storm water. If this were included, the volume actually treated per acre (*especially in the case of Beddington and South Norwood*) would be very greatly increased.

9. *Gallons of Sewage* (*exclusive of storm water*) *treated per acre per twenty-four hours.*

(*See* diagrams 1 and 4.)

	Gallons.		Gallons above or below the mean of 43,662.
Cambridge - - - -	121,600	Average 43,662 gallons.	+ 77,938 (about 178 per cent.)
Beddington - - - -	57,100		+ 13,438 (about 31 per cent.)
Altrincham - - - -	46,000		+ 2,338 (about 5 per cent.)
Rugby - - - - -	42,800		— 862 (about 2 per cent.)
Aldershot Camp - - -	25,000		— 18,662 (about 42 per cent.)
Nottingham - - - -	23,300		— 20,362 (about 46 per cent.)
Leicester - - - -	21,500		— 22,162 (about 50 per cent.)
South Norwood - - -	12,000		— 31,662 (about 72 per cent.)

These figures are arrived at by dividing the dry weather flow of sewage by the average area irrigated at one time.

As might be anticipated, the filtration farms in general treated much more sewage per acre than those where surface irrigation was followed. Cambridge, Nottingham, Aldershot Camp and Altrincham are filtration farms; the others are surface irrigation with some filtration, the proportion of filtration being greatest at Beddington.

Beddington and Rugby were treating a large volume of sewage, considering that they are combined surface irrigation and filtration farms. This is, in part, explained by the fact that Beddington was "working" only 16 per cent. and Rugby only 20 per cent. at one time of the total irrigable area. In other words about five-sixths and four-fifths respectively of the total irrigable areas were "resting."

* Part IV.: Engineering and Practical Report.

The remarkable difference between the volumes of sewage treated per acre at Cambridge and at South Norwood (the two extremes) is worthy of comment. The former farm dealt with ten times the volume of sewage and approximately ten times the amount of organic matter that the latter did. The two sewages do not differ greatly in strength, so leaving out of account in the meantime quality of effluent, it is obvious that a filtration farm may be used to treat far more sewage than a surface irrigation farm. But, as will presently be shewn, the soil at Cambridge is admirably adapted for sewage purification, whereas the soil at South Norwood is not very well suited for this purpose.

We have already pointed out that, in our opinion, the basis for calculating the area of land required for sewage purification should certainly not be the population relative to the total acreage of the farm, nor even the population relative to the total irrigable area; but that the latter factor should be taken in conjunction with the volume and strength of sewage, and with the quality and *effective* purifying area of the soil and subsoil.

It will be noted that on the average the farms were treating 43,662 gallons per acre at one time.

10. *Gallons of Sewage treated per acre per 24 hours, on the assumption that each acre of the irrigable area is under sewage during the whole time.*

(*See* diagrams 1 and 4.)

	Gallons.		Gallons above or below the mean of 12,427 gallons.
Cambridge	30,400	Average 12,427 gallons.	+17,973 (about 144 per cent.)
Altrincham	23,000		+10,575 (,, 85 ,,)
Nottingham	10,750		—1,677 (,, 13 ,,)
Beddington	9,500		—2,927 (,, 24 ,,)
Rugby	8,500		—3,927 (,, 32 ,,)
Aldershot Camp	8,300		—4,127 (,, 33 ,,)
Leicester	5,370		—7,057 (,, 57 ,,)
South Norwood	4,000		—8,427 (,, 68 ,,)

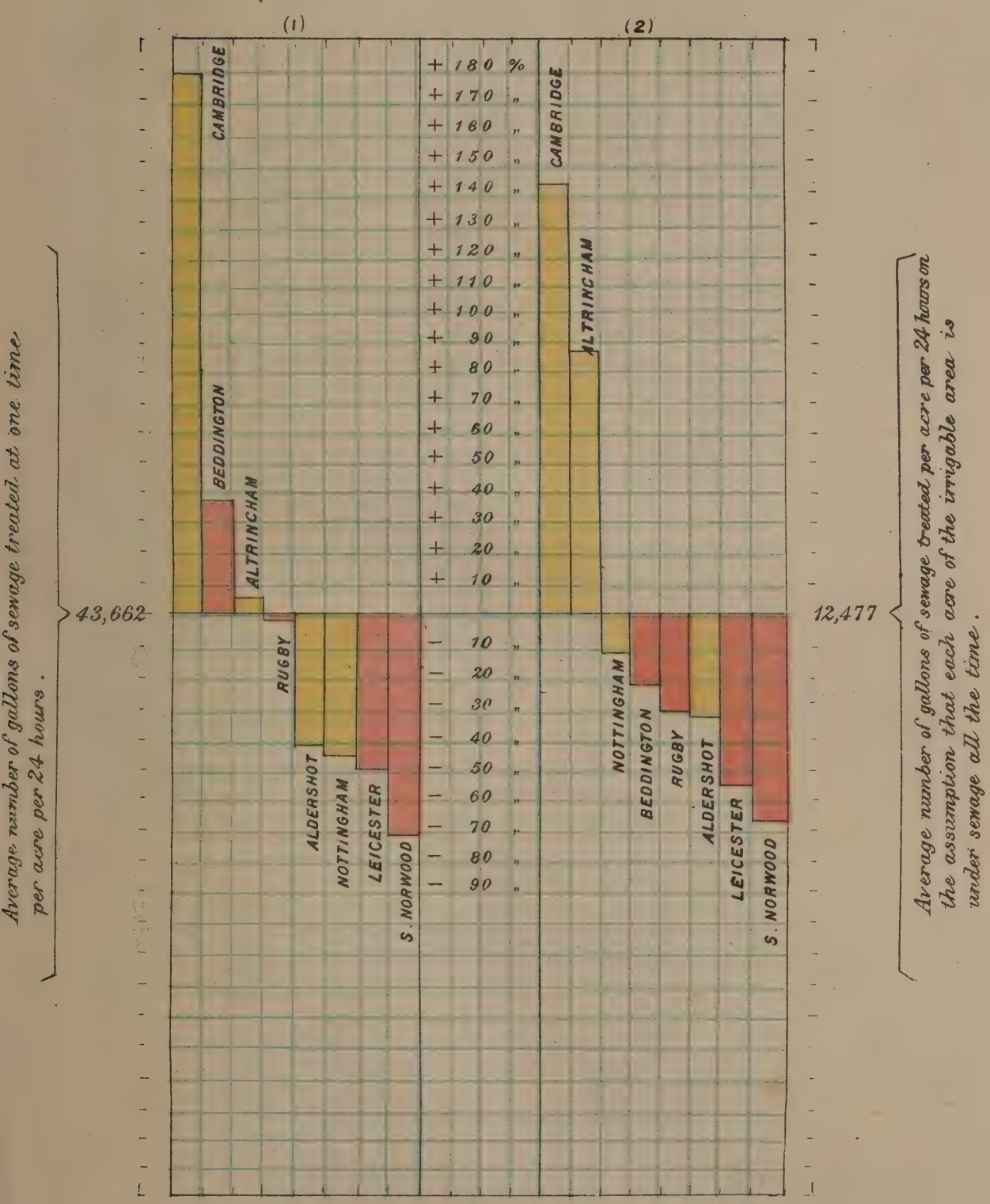
These figures are obtained by dividing the dry weather flow of sewage by the total irrigable area, and they are given here in order to facilitate comparison.

It will be seen that whilst Cambridge still occupies the first place, Altrincham is now second instead of third on the list, Nottingham has come from the sixth to the third place, and Beddington has fallen to the fourth place; then follow Rugby, Aldershot Camp, Leicester and South Norwood, the two last unchanged in order.

It must be definitely understood that the above figures are for comparative purposes only; they do not represent the volumes of sewage actually being treated per acre per 24 hours, but the volumes of sewage that would be treated per acre per 24 hours if the whole, instead of only a certain proportion, of the total irrigable area were being continuously sewaged. The figures thus obtained allow of a direct comparison being made between different sewage farms and between sewage farms and artificial processes of sewage treatment, so far as surface acreage is concerned. The results of isolated analyses of effluents must of necessity be compared with the volume of sewage being *actually treated per acre* of the total irrigable area at the time those samples of effluents were drawn; but if it were possible to calculate the absolute average quality of the effluents throughout the complete cycle of the intermittent treatment on the whole of the irrigable area, or, better still, throughout the whole year, then the comparison would be made with the volume of sewage treated per acre of the *total* irrigable area. At first sight this point may not be very obvious, but a reference to the figures given under headings 9 and 10 will make it

Diagram 4.

Percentage above or below the mean of the average number of gallons of sewage treated per acre per 24 hours reckoned (1) on the average area irrigated at one time; and (2) on the assumption that the whole of the irrigable area is under sewage at one time.*



The yellow colouring refers to the Filtration Farms; the red colouring to the combined Surface Irrigation and Filtration Farms.

* *Exclusive of storm water.*

3311. 1. 03.

Weller & Grahams. Ltd Litho. London.

clear. Thus Cambridge, which actually treats on the average 121,600 gallons of sewage per acre per 24 hours, would treat theoretically 30,400 gallons (one-quarter of the above) per acre of the total irrigable area. In other words three-quarters of the soil is at rest in actual practice and one-quarter at work. Again, Nottingham, though actually treating 23,300 gallons per acre per 24 hours, treats theoretically 10,750 gallons (rather less than one-half of the above) per acre of the total irrigable area. Thus, at Nottingham, twice as much of the total irrigable area proportionately is utilised at one time for purification purposes as at Cambridge. This is a point of great importance because, although Cambridge actually treats at one time about five times the volume of sewage per acre treated by Nottingham, it really treats less than three times the volume per acre per annum. The difference thus arises from the fact that, while Cambridge rests three-quarters of the total irrigable area, Nottingham rests one-half.

It is impossible to lay down any hard-and-fast rule as regards the proper proportions between the area actually being irrigated at one time and the surplus ("resting") irrigable area. Each case must be judged on its own merits, but broadly speaking the tentative assertion that at least (a) four-fifths of a surface irrigation farm and (b) two-thirds of a filtration farm respectively should be at rest, is probably not remote from the truth, it being assumed that (a) one-fifth, and (b) one-third are capable of effectively purifying the sewage until such time as the next one-fifth and one-third respectively of the surplus irrigable area, due in rotation, have been sufficiently rested. The above is subject to the reservation that the whole question of intermittency is but little understood, and, as we have said before, whether or not rapid or slow alternations of working and rest are advisable we are unable to say.

The working of a sewage farm involves the personal equation and, if a competent manager finds that it makes for the general purity of the effluents to vary his plans of procedure according to the flow of sewage, the season of the year, the varying capacity of different areas of the farm efficiently to treat the sewage, and other factors too numerous to mention, we think that within reasonable limits his judgment may be trusted.

As has just been said, whether the periods of intermittency should be long or short is a moot point; but there can be no question that the surplus ("resting") irrigable area should be considerably in excess of the average area irrigated at one time ("working area"). Were it reasonably practicable, we should press both for a larger area being irrigated at one time than is at present considered necessary, and for a more than proportionately larger area (surplus irrigable area) being set aside for "resting" purposes and for the formation and the storing of oxidised nitrogen.

11. *Characters of the Sewage.*

The following figures give the order in which the sewages may be *roughly* arranged according to strength (from the strongest to the weakest), as judged by chemical analysis.*

1. Aldershot Camp 6. South Norwood	Domestic.
2. Rugby 5. Beddington (Croydon) 7. Cambridge 8. Altrincham	Mainly Domestic.
3. Nottingham, four-sevenths domestic, three-sevenths trade refuse.	
4. Leicester, three-fourths domestic, one-fourth trade refuse.	

* The "strength" of the sewage is usually best judged by chemical analysis. For the bacteriological results reference must be made to the Bacteriological Report (Part III.). On the whole, Altrincham, Cambridge and Leicester were weak sewages from the bacteriological point of view. The others varied from medium to strong sewages.

The farms themselves are here arranged according to whether they are treating domestic, mainly domestic, or mixed sewage. There seems to be little doubt that, although sewage containing a large amount of trade refuse can be treated satisfactorily on land, the presence of the latter has some inhibitory effect on the purification.

But there is also the important question of the strength of the sewage. It is true that the volume of the sewage is considered by some authorities to be of as great, if not greater, importance, than its strength, but this proposition is to be accepted with some limitations. It is probably as easy to reach a given standard *percentage* purification (*i.e.*, effluent as compared with its corresponding sewage), with a strong sewage of small volume, as with a weak sewage of large volume. But, if we elect to go by a fixed standard of actual results, irrespective of the strength of the sewage and of the volume of the effluent, it is quite certain that a weak sewage of large volume can be more readily brought within the limits of such a standard than a strong sewage of small volume.

To some extent this difficulty is overcome by modifying the standards at present in vogue, pitting against a slight excess of organic matter in an effluent a reserve of oxidised nitrogen and determining the degree and rate of fermentability of the liquid. Further, it would be logical, although perhaps impracticable, to take into account the ratio of the volume of the effluent to that of the water of the river into which the effluent is being discharged, and to demand a purification *pro rata* with the volume of the effluent, in which case a weak sewage of large volume might be required to yield a purer effluent than a strong sewage of small volume. It is to be noted, for example, that in some towns the sewage is very weak, and can be fairly easily "treated" so as to yield an effluent that will pass existing standards of purity without necessarily reaching a high percentage degree of purification as compared with the original sewage, and without sufficient oxidation having taken place. Yet the volume of such effluents in relation to the volume of the rivers into which they are being discharged may be very great. Or, to take a suppositional case, one town may be abstracting from a river water for waterworks purposes at the rate of 40 gallons per head of the population per day, while another town under otherwise parallel conditions is using 20 gallons. Both these towns, let us say, adopt the same methods for sewage purification purposes. Are we to conclude that the effluents from those two towns, similar in respect of population and other circumstances, but the one discharging twice the volume of effluent into its particular river, are to be judged by the same standard, notwithstanding that the volume of the polluting liquid in the former case exceeds that of the latter by 100 per cent.? (Compare "Chemical conclusions" to this Report; Sub-section on Standards).

It might indeed be contended that the town with the strong sewage of relatively small volume should use the same area of land or of bacteria beds (double the area per unit of sewage) as the town with the weak sewage of relatively large volume. But this does not touch the question of the difference in the volume of the effluent in the two cases, or the fact that the effluent from the weak sewage might, as judged by standards of degree and rate of fermentability, be less pure than the effluent from the strong sewage.

The strength of the various sewages can be best judged by referring to the Chemical Report (Part II.). But an abstract of some of the results may be given, in order that an idea may be formed of the strength of the sewage which the soil at each of the above eight sewage farms was being called upon to treat.

1. *Aldershot Camp Farm.*

This sewage is purely domestic and is very strong, more especially as regards ammonia and organic nitrogen. It has, however, such a short distance to travel before it reaches the farm that the screening of the grosser solids from it is very easy; and hence, although it is only allowed one hour's stay in the settling tanks, the amount of suspended solids in the sewage as run on to the land is not excessive.

The hourly* samples, in three sets of 24 hours each, gave the following average figures :—

——	Parts per 100,000.
Total Nitrogen	13·3
Total Organic Nitrogen	5·1
Albuminoid Nitrogen	1·62
"Oxygen absorbed" from permanganate in four hours at 26·7° C. (80° F.)	20·8
Chlorine	15·0
Solids in suspension	36·6
(Containing "Cellulose")	4·0

2. *Rugby Farm.*

This sewage is domestic, excepting that it contains a large quantity of oil from an engine works, which is skimmed off twice a day from the surface of the settling tanks, because of the injury that it formerly caused to the growing rye grass. The sewage is screened and settled after arriving at the farm. On arrival it is in a fairly fresh condition and not well broken up.

Three sets of hourly samples gave the following results :—

——	Parts per 100,000.
Total Nitrogen	9·7
Total Organic Nitrogen	3·3
Albuminoid Nitrogen	1·7
"Oxygen absorbed" in four hours	18·4
Chlorine	10·0
Solids in suspension	47·3
(Containing "Cellulose")	7·2

3. *Nottingham Farm.*

This sewage contains about 40 per cent. of its volume of trade refuse from a variety of sources. It is only partially screened, but owing to its long journey, arrives at the farm in a well broken up condition.

Three sets of hourly samples gave the average figures :—

——	Parts per 100,000.
Total Nitrogen	7·7
Total Organic Nitrogen	3·2
Albuminoid Nitrogen	1·8
"Oxygen absorbed" in 4 hours	23·2
Chlorine	13·7
Solids in suspension	52·0†
(Containing "Cellulose")	8·9†

* The hourly samples were all drawn in equal volumes per hour, and *not* according to rate of flow (*cf.* Part II. Chemical Report).

† This figure is probably higher than the normal, owing to rain washing out the sewers on one of the days just before the hourly samples began to be drawn.

4. *Leicester Farm.*

This sewage contains about one-fourth of its volume of trade refuse of different kinds, this refuse being largely of an objectionable nature.

It is screened and settled, the settlement being for about two hours or a little longer.

The sewage, though of moderate strength as regards nitrogenous matter, contains relatively a large proportion of oxidizable substance, as measured by the "oxygen absorbed" test, this being without doubt due to some of the manufacturing refuse present. The sewage arrives at the farm in a well broken up condition.

Three sets of hourly samples gave the following figures :—

———	Parts per 100,000.
Total Nitrogen	8·1
Total Organic Nitrogen	2·3
Albuminoid Nitrogen	1·2
"Oxygen absorbed" in 4 hours	22·4
Chlorine	13·4
Solids in suspension	34·1
(Containing "Cellulose")	6·2 (Two analyses).

5. *Croydon* (*Beddington*).

The sewage is practically all domestic. The whole of it is screened, and in addition one-quarter of it passes through small settling tanks, in which however the settlement is very inadequate.

Seven sets of hourly samples gave the following figures :—(Some rain fell on two of the days when they were drawn).

———	Parts per 100,000.
Total Nitrogen	7·2
Total Organic Nitrogen	2·1
Albuminoid Nitrogen	0·9
"Oxygen obsorbed" in 4 hours	12·5
Chlorine	8·3
Solids in suspension	34·5

6. *South Norwood Farm.*

This sewage is purely domestic.

Excepting a small portion which is settled only, it is screened and settled. Judging from the low figures obtained for suspended solids, the settlement must be on the whole good.

Seven sets of hourly samples gave the following results :—

———	Parts per 100,000.
Total Nitrogen	5·2
Total Organic Nitrogen	1·5
Albuminoid Nitrogen	0·7
"Oxygen absorbed" in four hours	7·7
Chlorine	7·5
Solids in suspension	21·9

7. *Cambridge Farm.*

The sewage is almost purely domestic, and it is rather weak. From the centre of the town to the farm is a distance of about 3¼ miles, so that, with the screening at the pumping station and the breaking-up action which the pumps exert, the sewage arrives at the farm in a well broken up condition. It receives only about half an hour's settlement in one tank at the farm.

Three sets of hourly samples* (stronger than the chance samples, which was unusual) gave :—

———	Parts per 100,000.
Total Nitrogen	5·7
Total Organic Nitrogen	1·9
Albuminoid Nitrogen	0·9
"Oxygen absorbed" in four hours	10·1
Chlorine	8·5
Solids in suspension	26·5
(Containing "Cellulose")	4·5

8. *Altrincham Sewage Farm.*

The Altrincham sewage may be taken as purely domestic, there being practically no trade refuse in it. It contains the washings from streets, roofs and backyards during storms. The sewage is weak, and it arrives at the farm in a fairly fresh condition.

No sets of hourly samples were taken, only four chance samples of sewage and five of lagoon liquor, the latter being if anything the stronger. As has been stated in the Engineering Report, there is practically no tank settlement at the farm. There was nothing unusual about the samples of sewage examined, the amounts of suspended matter in them being moderate ; the lagoon liquors were turbid and had a sewage smell.

The following average figures were obtained from four chance samples of sewage and five of lagoon liquor (taken together), but they can only of

* A considerable amount of rain fell while the first set of hourly samples was being drawn, but all three sets were very uniform in composition.

course be looked upon as very approximate. They are, however, sufficient to show the dilute character of the sewage :—

——	Parts per 100,000.
Total Nitrogen	3·56
Total Organic Nitrogen	2·29
Albuminoid Nitrogen	0·62
"Oxygen absorbed" from permanganate in four hours at 26·7° C. (80° F.)	5·22
Chlorine	9·43

It is desirable to bring some of the facts set forth in subsections 10 and 11 together in diagrammatic form. This has been done in diagram 5, which shows approximately the *relative* proportions of (*a*) albuminoid nitrogen; (*b*) total organic nitrogen; (*c*) total nitrogen; (*d*) oxidisable matter as measured by the 4 hours "oxygen absorbed" test at 26·7° C. (80° F.), which are treated by seven of the sewage farms per acre of the total irrigable area.

These figures are arrived at by multiplying the average figures obtained in the analysis of the *hourly* samples of sewage by the respective volumes treated per acre of irrigable area. They are merely *relative* figures, *not* parts per 100,000.

Name of Farm.	Gallons of Sewage per acre of Irrigable Area.	Albuminoid Nitrogen.	Total Organic Nitrogen.	Total Nitrogen.	"Oxygen Absorbed" from Permanganate.
Cambridge	30,400	2·77	5·7	17·4	30·7
Aldershot Camp	8,300	1·34	4·2	11·0	17·3
Nottingham	10,750	1·56	3·4	8·3	25·0
Rugby	8,570	1·48	2·8	8·3	15·8
Croydon (Beddington)	9,520	0·87	2·0	6·8	11·9
Leicester	5,370	0·64	1·3	4·4	12·0
South Norwood	4,000	0·28	0·6	2·1	3·1

This table of figures and the corresponding diagram take no account of storm water, much more of which is treated at Beddington and South Norwood than at the other farms. Further, the inequalities due to drawing the hourly samples in equal volumes per hour, instead of in volumes proportionate to the rate of flow, would be greater in some cases than in others.

Alongside of the above diagram it is of interest to place diagram 6, which shows the *relative* volumes of sewage, irrespective of their strength, treated per acre of the total irrigable area; and, in order to give an approximate idea of the actual strength of the sewages, the results of the analyses of the hourly sets of samples are grouped together in diagrams 7 and 8 (*cf.* also sewage diagrams in Part II., Chemical Report).

Taking into account both the "chance" and hourly samples, the following general bacteriological statement applies to the average biological composition of the sewage from the above eight farms :—

Total number of bacteria (gelatine at 20° C.):—More than ten million bacteria per c.c.

Total number of bacteria (agar at 37° C.):—More than one million but less than ten million per c.c.

Diagram 5.

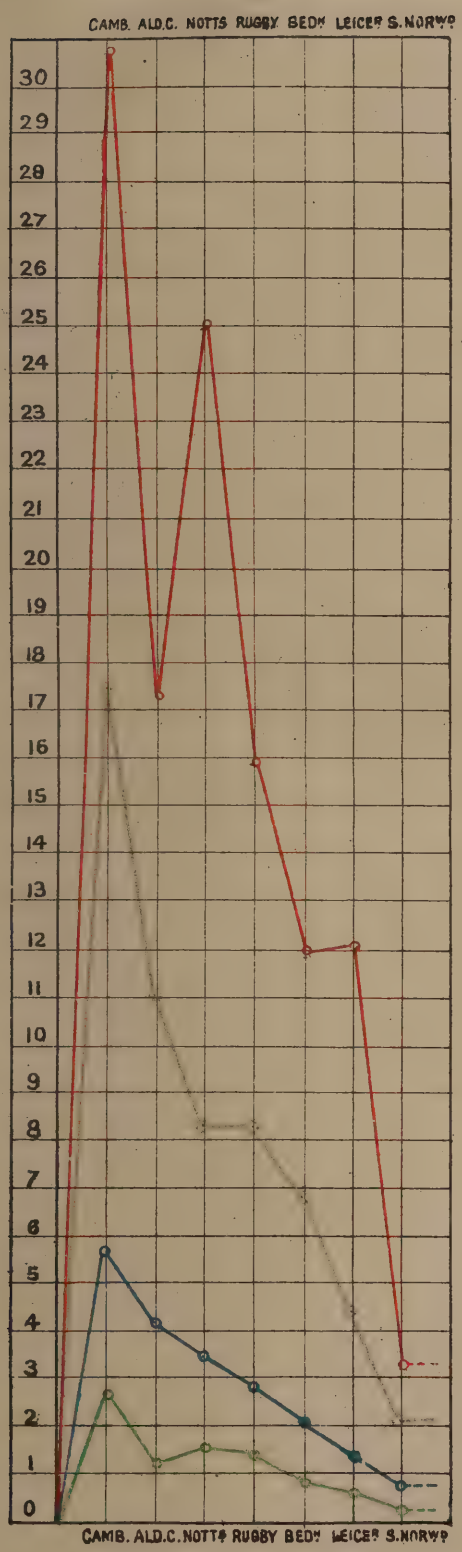


Diagram to indicate approximately the relative proportions, of

(A) Albuminoid Nitrogen.

(B) Total Organic Nitrogen.

(C) Total Nitrogen

(D) Oxidizable matter as measured by the 4 hours "Oxygen absorbed" test at 26·7° C. (80° F.)

which are treated per acre by the seven Sewage Farms undermentioned, on the assumption, for purposes of comparison, that each acre of irrigable area is under sewage all the year round.

The Farms are

1 CAMBRIDGE
2 ALDERSHOT CAMP.
3 NOTTINGHAM
4 RUGBY
5 CROYDON (Beddington)
6 LEICESTER
7 SOUTH NORWOOD

Notes.

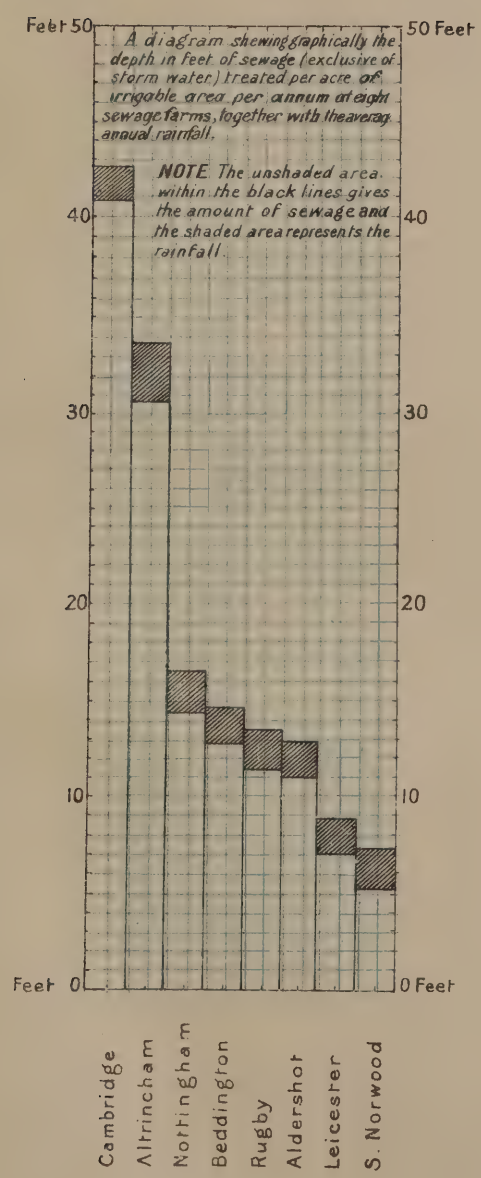
1 *Those curves are arrived at by multiplying the average figures obtained in the analysis of the Hourly Samples of Sewage by the respective volumes treated per acre of irrigable area.*

2 *The figures in the vertical line of this diagram indicate merely relative, not absolute, amounts, i.e. not parts per 100.000.*

3332.2.03.

Weller & Graham, Ltd Litho. London.

Diagram 6.



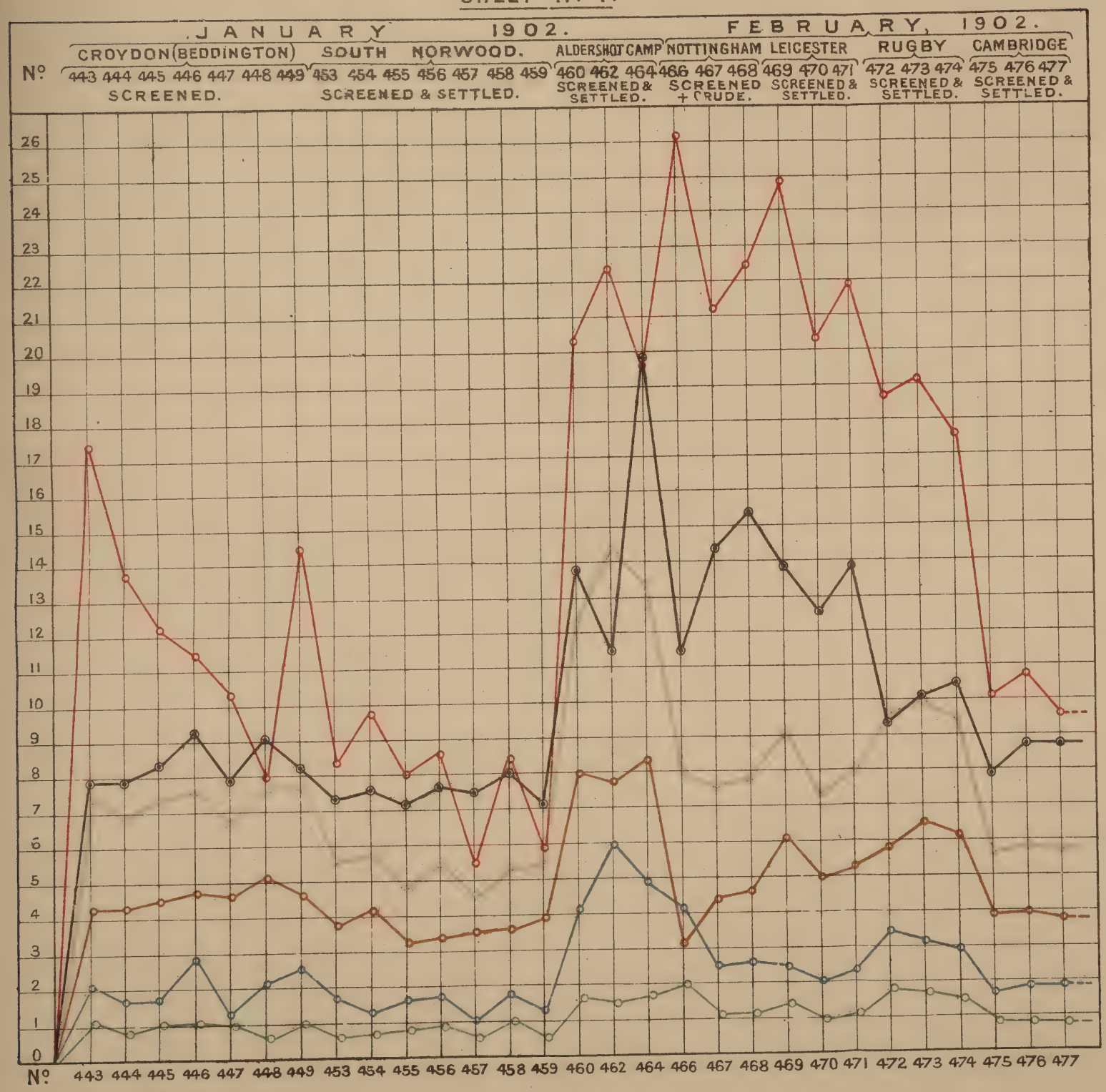
Weller & Graham Ltd Litho. London.

Diagram 7.

SEWAGE FARMS.

SETS OF HOURLY SEWAGE SAMPLES FROM SEVEN DIFFERENT FARMS. CURVES.

SHEET No. 1.



Note

Each sample number represents a mixture of 24 hourly samples, taken in equal quantities per hour.

REFERENCE

Parts per 100.000, by Weight.

Albuminoid Nitrogen..... Shewn thus ——

Organic Nitrogen by Kjeldahl, with Reduction..... ——

Ammoniacal Nitrogen..... ——

Total Nitrogen by Kjeldahl, with Reduction..... ——

"Oxygen absorbed" from Permanganate at 26·7°C (80°F.) in four hours..... ——

Chlorine (Combined)..... ——

Note

Figures in the Vertical line represent "Parts per 100.000."

Figures in the Horizontal line represent the numbers of the Samples analysed.

A dotted line is used when there is a break in the curve.

3332. 10. 02.

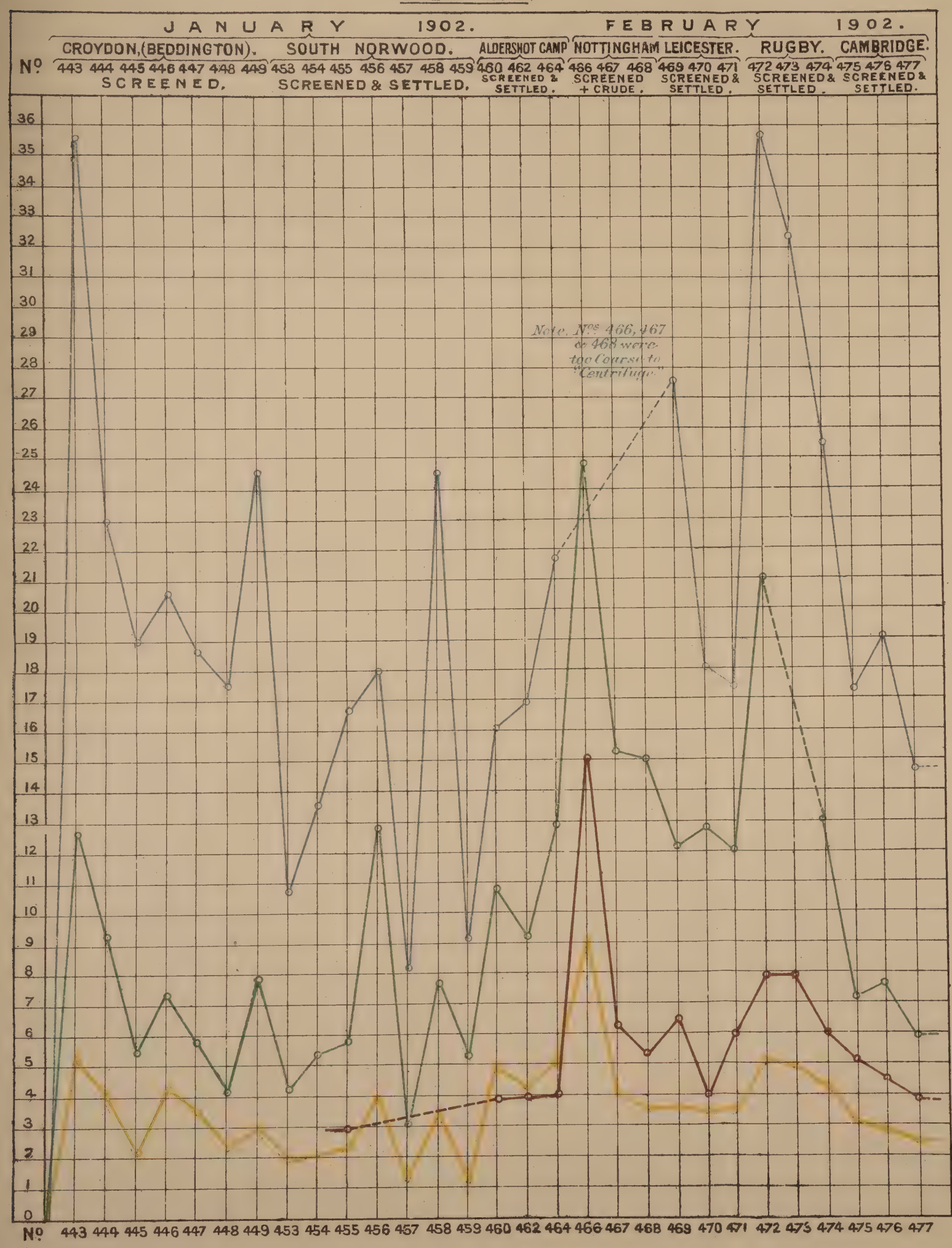
Weller & Graham Ltd Litho. London.

Diagram 8.

SEWAGE FARMS.

SETS OF HOURLY SEWAGE SAMPLES FROM SEVEN DIFFERENT FARMS. CURVES.

SHEET Nº 2.



Note
Each sample number represents a mixture of 24 hourly samples, taken in equal quantities per hour.

REFERENCE

Parts per 100.000, by Weight.

Solids in Suspension (Gravimetrically) (Scale divided by 10) ---------

Cellulose. ----------

Cellulose (still containing fat) ---------

Parts per 100.000. by Volume.

Solids in Suspension (by Centrifuge) (Scale divided by 10) . . . .

Note
Figures in the Vertical line represent "Parts per 100.000."

Figures in the Horizontal line represent the numbers of the Samples analysed.

A dotted line is used when there is a break in the curve.

3332. 10. 02.

Weller & Graham Ltd Litho. London.

B. Coli (and closely allied forms) :—About 100,000 per c.c.

Spores of B. Enteritidis Sporogenes (Klein's "Enteritidis change" in anaerobic milk cultures):—Usually a positive result with $\frac{1}{100}$ to $\frac{1}{1000}$ c.c.

Indol test:—Usually a positive result with $\frac{1}{100,000}$ c.c.

"*Gas*" *test* ("gas" in gelatine "shake" cultures within 24 hours at 20° C.):—Usually a positive result with $\frac{1}{100}$ to $\frac{1}{1000}$ c.c.

Neutral red broth test:—Usually a positive result with $\frac{1}{100,000}$ c.c.

12. *Method of Treatment.*

Aldershot Camp - -	Screening and settling tanks.	Land filtration. (The term "filtration" is used broadly in the same sense as the older term "intermittent downward filtration.")
Altrincham - -	Settling tank.	
Cambridge - - .	Screening and settling tank.*	
Nottingham - -	Screening (partial).†	
Beddington - -	Screening.	Surface irrigation with some filtration. (The term "surface irrigation" is used in much the same sense as the older term "broad irrigation.")
Leicester - - -	Screening and settling tanks.*	
Rugby - -	Screening, occasional chemical precipitation and settling tanks.	
South Norwood - -	Screening and settling tanks.	

* All the sewage is pumped to the farm.

† A part only of the sewage is pumped.

In the case of Aldershot Camp, Altrincham, Cambridge and Nottingham, land filtration was employed. Beddington, Leicester, Rugby and South Norwood sewage farms are examples of surface irrigation with some filtration, the above order representing probably fairly well (from the greater to the less) the relative amount of true filtration. It is impossible, however, to come to any absolute conclusions with regard to the relative amount of filtration which takes place. Many surface irrigation farms are underdrained to some extent, in order to facilitate the "drying off" of those portions of the ground where the sewage would be likely to stagnate, and in such cases filtration necessarily occurs. Moreover, there are but few farms with soil of so impervious a character as not to allow of some filtration both in a downward and a lateral direction. The "creeping" of the sewage over the surface of the soil which takes place in the (so-called) surface irrigation method of sewage purification must inevitably result in some degree of surface filtration. Particularly is this likely to occur where the land has been recently ploughed, and also where the soil has been lightened by the addition of cinders, etc. A surface irrigation farm is thus to some extent a surface filtration farm.

It will be noted that the terms "filtration" and "surface irrigation" are used in place of the older terms "intermittent downward filtration" and "broad irrigation." The reasons for so doing may be briefly given as follows :—In the first place "intermittency" is essential whether "surface irrigation" or "filtration" is employed, so that if the term "intermittent" is to be retained, it should be used alike for the two different methods of treatment. But we think it better to employ it in neither case. Further, the term "downward" would seem to be superfluous in connection with land treatment, and, if stress is laid on this term, an impression is apt to be created that a similar action never takes place where surface irrigation is employed. Moreover the term "surface" irrigation seems to define what takes place better than the expression "broad" irrigation.

As regards the screening arrangements, it will be seen that the sewage is not screened at Altrincham; at Nottingham the screening is only partial; and at Beddington screening with practically no settlement in tanks is in operation. The rest of the farms screen and settle their sewage, and Rugby occasionally employs chemical precipitation as well.

When pumping is required it is important to have screens to protect the pumps, apart altogether from the general advantages of screening as a

preliminary to further treatment. As previously explained, "fresh" sewage can be so screened as readily to separate much of the paper and fæces, the screenings being in a condition to be easily manipulated and having a definite manurial value. But when the sewage is in a disintegrated condition, even graded screens may prove of little use. It is important that arrangements should be made for the rapid disposal of all screenings, as otherwise they constitute an unsightly nuisance, and one very appreciable to the senses.

As regards the question of settling tanks and sludge disposal, much depends on the quality of the soil of the farm. For example, a poor sandy soil is capable of dealing with sludge in considerable amount without deterioration, in fact, with probable improvement. In such cases, adequate settling tank accommodation is far less necessary than where heavy soils are concerned. Of course, the better the settlement, the greater the amount of sludge, but to deal separately with the sludge is to choose the lesser evil when land is not of the proper kind to absorb sludge readily. When the land is of such a nature as to make it important to eliminate as far as possible the heavier suspended matter in the sewage, the customary rule of having a *total* tank capacity equivalent to about 50 per cent. of the dry weather flow—of which not more than about two-thirds should be out of operation at one time—should certainly not be departed from.

It is a factor of importance that some of the above sewage farms have, throughout the long period of their working existence, disposed of the sludge on their own land.

13. *General Character of Soil and Subsoil on the Eight Principal Farms under observation.*

Land Filtration.	1. Nottingham - -	Sandy loam and gravel overlying gravel and sand,
	2. Cambridge - - -	Sandy loam overlying gravel and sand.
	3. Aldershot Camp - -	Coarse sand overlying very fine sand.
	4. Altrincham - -	Peaty soil overlying sand and gravel.
Surface irrigation with some filtration.	5. Beddington (Croydon)	Gravelly loam overlying gravel and sand.
	6. Rugby - - -	* Heavy loam overlying stiff clay, in which, however, pockets of gravel are present.
	7. Leicester - - -	Stiff clayey soil overlying dense clay.
	8. South Norwood - -	A clay soil resting on London Clay.

* *Note.*—The Rugby soil was looked upon as a heavy loam when the farm was first inspected, and this classification is retained. According to the mechanical analysis, however, it is more of a clay than either Leicester or South Norwood.

If we exclude for the moment a chalky soil overlying Chalk, the above soils may be taken as representing fairly well, within broad limits, the kinds of soil which are used, or which are likely to be used, for the purification of sewage. They may be condensed roughly into the four groups :—

1. Sand overlying finer sand.
2. Peaty soil and sand overlying gravel and sand.
3. Light loam overlying gravel and sand.
4. Heavy loam or Clayey soil } overlying clay.

But, as everyone knows, the difference between some of the soils is one of degree rather than of kind, a light loam gradually merging into a sandy soil on the one hand and into a heavy loam on the other, and a heavy loam in its turn merging into a clay.

In the section of the Chemical Report which treats of Soils, this subject is discussed at some length. By referring to this section it will be seen that the main factors are :

1. The number of particles in unit weight of soil.
2. The size of the air spaces between those particles.
3. The proportion of humus or modified organic matter which the soil contains.

When the air spaces are individually very small, as in the case of clay soils, the friction between the water and the soil particles is so great that filtration becomes impossible, or practically so.

The importance of making a careful mechanical analysis of the soil and subsoil through which it is proposed to filter sewage (at all events when these are of a porous character) is thus at once evident. If a sufficient number of such analyses were available for reference, they would afford valuable data as to the volume of sewage of given strength which any particular soil might reasonably be expected to purify. One point, however, requires to be specially emphasized here, viz., the necessity for very careful sampling of soil and sub-soil. Though one may speak, for instance, of land as consisting of soil and subsoil of a given type, our experience is that these are often apt to show considerable variations within narrow limits of area. And this, of course, adds to the difficulty of managing a sewage farm well, for the dose of sewage should be regulated according to the purifying capacity of the particular plot under irrigation at the time.

As might be anticipated, the porous soils with pervious subsoils (with the exception of the greater part of the Beddington Farm) are under-drained and used as filtration areas, while the heavy soils on clay subsoils are employed, with or without drainage, mainly for surface irrigation. But it is impossible to draw a hard-and-fast line even here, because some filtration must undoubtedly go on in heavy soils and subsoils which are under-drained. (Cf. Parts II. and IV.; the Chemical and Engineering Reports on the Leicester Farm.)

To glance for a moment at the individual farms, taking the porous soils first:

At *Nottingham* the soil is largely composed of the finer classes of particles, but of the finest or "clay" class there is not a great deal. While, therefore, there is a large surface exposed by the particles of this soil, the air spaces are not too small to prevent comparatively easy filtration. Again, when aeration would otherwise become more difficult, the fine soil gives place to a coarse gravel.

The *Cambridge* soil and subsoil are very similar in mechanical composition to those of Nottingham, though containing rather fewer particles in a given volume. We should therefore expect these two soils and subsoils to effect much the same purifying action upon sewage, if they were used in the same way. But comparison is rendered difficult by the fact of the Nottingham farm being cropped, and the Cambridge farm for the most part uncropped; and also by Nottingham treating a medium volume of a strong sewage and Cambridge a large volume of a weak one. The very high percentage of lime in the Cambridge soil and subsoil, due to the lime treatment which the sewage received there for some years, is an interesting point. But that there is sufficient lime in the Nottingham soil and subsoil for assisting nitrification is evident from the admirable results which are achieved there.

The *Beddington* soil and subsoil, while generally of a similar nature to those of Nottingham and Cambridge, are distinctly coarser, *i.e.*, contain fewer particles per gramme. The excellent chemical results obtained during the special experiment (*see* Part II., Chemical Report) at Beddington show what a high class of effluent this soil and subsoil can produce when they are used for filtration. And the relatively large volumes of sewage, and relatively large aggregate amount of organic matter treated at Beddington by surface irrigation, when compared with the volumes, etc., at Leicester and South Norwood, further show that the surface irrigation at Beddington must be largely supplemented by filtration through the surface soil.

At *Aldershot Camp* the soil conditions are quite different from those at Nottingham, Cambridge and Beddington. A reference to the Chemical Report will show that the Aldershot Camp soil contains a much larger proportion of the coarser particles (including "sand") than the Nottingham soil, and much less of the "clay" particles; and that the total number of particles per gramme is relatively small in the Aldershot Camp soil. In the subsoils, on the other hand, the conditions are reversed, coarse particles largely predominating at Nottingham and fine particles at Aldershot. Thus, at Nottingham we have a fairly fine soil overlying a coarse gravelly subsoil, while at Aldershot a coarse "sandy" soil is superimposed on a subsoil of somewhat similar nature, but in which the finer constituents largely predominate. Apart from questions of relative

depths down to the drains, it is thus probable that the conditions for efficient aeration are less favourable at Aldershot Camp.

It is worth noting here, however, that a sandy soil can deal with a large amount of sludge, the decomposition and fertile properties of the latter being largely promoted by the addition of lime. And, of course, with increase of humus, the better does the sand become for sewage purification. How slowly this increase in modified organic matter goes on is shewn by the small percentage loss on ignition (3·6 per cent.) in the Aldershot Camp soil, which, originally sand pure and simple, has been in use as a sewage farm for thirty to forty years.

Only the surface soil of the *Altrincham* farm was analysed, and not the subsoil, and therefore few conclusions can be drawn here. The organic matter present (mostly decomposed peat) was very large in amount, and the total number of particles per gramme—mainly consisting of the finer particles—was very high also for a porous soil. On the other hand, the relative rate of filtration through this surface soil is rapid, owing no doubt to its low specific gravity (real and apparent), and, as a consequence of this, to the comparatively large size of the individual air spaces. The action of the Altrincham soil and subsoil, however, requires further investigation.

The difference between a clay soil and a light soil is of course due to the fact that the former contains a much larger proportion of the finer and, especially, of the "clay" particles per gramme. A glance at the figures of the mechanical analysis of the *Rugby* and *Leicester* soils, as compared with those of Nottingham, shows the difference in number of particles to be practically confined to this one class. As already mentioned, the effect of this large number of particles is greatly to lessen the sizes of the individual air spaces (though the aggregate air space in a clay is greater than in porous soil), and therefore to increase the difficulty of percolation and of aeration. The *South Norwood* soil gave unexpected results on analysis, being of a less clayey nature than was anticipated; this was presumably due to its having been lightened with ashes. It would be advisable, however, to examine another sample of this soil before drawing conclusions from it.

The Altrincham soil has already been instanced as consisting partially of decomposed peat. A few visits were paid to *Worsley* (Lancashire), where a portion of the sewage farm land consists of peat pure and simple. But apart from the inability of peat—partly because of its extremely spongy nature—to purify properly any reasonable volume of sewage, there are obvious practical reasons for not laying down permanent works on an unstable foundation.

In the Chemical and Bacteriological Conclusions of this Report a brief reference is made to the farm at *Luton*, where the sewage is treated on chalky soil overlying Chalk. At such a farm there are no effluents, owing to the fact of the Chalk being fissured in all directions. No analysis was made of the Luton surface soil, and hence no conclusions can be drawn with regard to it.

The different texture of the various soils and subsoils is well seen from the following short table, which gives *approximately* the *relative* numbers of particles in unit weights of the *ignited* soil and subsoil respectively.

Name of Farm.	Soil.	Subsoil.
Nottingham	100	100
Cambridge	75	61
Beddington	46	55
Aldershot Camp	19	394
Altrincham	157	—
Rugby	392	—
Leicester	269	—
South Norwood	177	—

Note.—The above table takes perforce no account of the particles of organic matter in the soil, and is therefore only of approximate value. The organic matter was especially abundant in the Altrincham surface soil (*cf.* Part II., Chemical Report: Section upon Soils).

14. *Separate or Combined Sewerage System.*

Aldershot Camp	Entirely separate Sewerage System	All the water capable of being separated is carried off by separate sets of pipes and not treated in any way.
Cambridge Beddington (Croydon) Leicester South Norwood Rugby	Partially separate Sewerage System	Water from the street pavements and front roofs of houses is carried off by a separate set of pipes, and not treated in any way.
Altrincham Nottingham	Combined Sewerage System	One set of pipes (sewers) takes all the roof, street and backyard water, as well as the sewage proper to be treated (subject to storm overflows).

Whether it is better to have a separate or a combined sewerage system is a controversial matter, and we content ourselves by briefly referring to some of the advantages and disadvantages of each system. As we have been careful to point out elsewhere, "street washings" (liquid from the separate system) may be so impure as to render its discharge into rivers undesirable. Since the separate system is seldom carried out in its entirety, we confine our remarks to the partially separate sewerage system. For the sake of simplicity our comments may be confined to a brief consideration of the advantages and disadvantages of the separate system.

SEPARATE SYSTEM.

Advantages.	*Disadvantages.*
Fluctuations in the sewage flow at the outfall works are reduced during storms.	The occasional natural flushing out of the sewers is lessened. Nevertheless it is chiefly during dry weather that the sewers require flushing.
The road detritus is kept out of the sewers.	
A smaller area of land is required for irrigation purposes at a time when the soil of the sewage farm is already apt to be saturated with rain water.	The dilution of the sewage with rain water is lost to some extent, but against this must be put the increase of total volume of liquid to be dealt with at places where the combined sewerage system is in use, and the fact that "street washings" *per se* may be of objectionable quality.
	Instances are not unknown when, through carelessness, the foul water house drains have been connected up to the pipes of the separate system.
The routine working of the sewage farm is not embarrassed by frequent fluctuations in the volume of sewage, amounting it may be to three or four times the normal.	The initial cost and maintenance are greater with the separate system, but whether this disadvantage is not more than counterbalanced by, among other things, the larger volume of liquid to be "treated" at the disposal works, is a difficult point to determine.
If the sewage is pumped, the extra cost of dealing with such increases of flow due to storm water, as are dealt with at the disposal works, is considerably lessened. A saving of cost would also seem to occur in precipitation schemes.	
In districts where the rainfall is heavy, the rain water is carried rapidly away, and flooding of the low-lying levels of the town is less likely to occur. Sewers even of large capacity may be quite incapable of dealing satisfactorily with these sudden fluctuations of flow.	

If it were practicable to carry off *all* the storm water rapidly and in addition to treat efficiently the *whole* of the *combined volume* of storm water and sewage at the disposal works, then it is obvious that the combined system would be preferable. But as this would seem to be impracticable, the question largely resolves itself into whether it is better to have (a) a combined system with the storm overflows working at low dilutions, or (b) a separate system with storm overflows coming into operation only very exceptionally—*i.e.*, at higher dilutions. We have not sufficient data to formulate a decided opinion, the more so since adequate records are not available of the average quality of the liquids under (a) and (b) sets of conditions, the results being interpreted in the light of the analyses of "street washings" liquid *per se.*

15. *Rivers or Brooks into which the final effluent is discharged.*

—	The Effluents discharge into	Approximate ratio between the dry weather flow of effluent and the volume of river water.
1. Nottingham -	River Trent - - -	About 1:160 (at time of sampling).
2. Rugby - - -	River Avon - - -	About 1:30 (at second time of sampling)
3. Cambridge - - -	River Cam - - -	About 1:15 (normally).
4. Beddington (Croydon)	River Wandle - -	About 1:12 (at first time of sampling).
5. Aldershot Camp - -	River Blackwater - -	About 1:6 (normally).
6. Altrincham - - -	Sinderland Brook - -	About 1:3 (normally).
7. Leicester - - -	Anstey Brook (adjoining River Soar) - -	About 1:1 (at time of sampling).
8. South Norwood - -	Chaffinch Beck - -	About 3:1 (at second time of sampling).

In the above table the farms are arranged in the order in which the effluent is most highly diluted with river water. Nottingham and Rugby effluents are diluted over one hundred times and about thirty times respectively with river water; Beddington and Cambridge over ten times; Aldershot Camp and Altrincham, six and three times respectively; Leicester equal volumes; while the South Norwood effluents increase the volume of Chaffinch Beck three times. The above approximate figures were arrived at by comparing the dry weather flow of the sewage with the normal flow of the river, or with the flow of the river at the time of sampling (*see* Part IV., Engineering Report).

It must be remembered that the volume of a river varies to a greater extent than the volume of an effluent. Hence a volume of effluent, which when discharged into a river may be a nuisance during dry and sultry weather, may be free from objection during wet and cold weather.

The chemical and biological qualities of the rivers above and below the effluent outfalls will be considered elsewhere. Here we propose only to consider very briefly the effect of the discharge of the effluents into the different rivers as judged by the senses.

The River Trent above the effluent outfalls was not perhaps in as satisfactory a condition as might have been wished, and certainly the Nottingham effluents did not seem in any way to increase the impurity of the water. Chemically, they exerted a purifying action. It has been noted elsewhere that the "untreated" sewages from several villages (notably Radcliffe) on the banks of the Trent discharge into the river above the Nottingham sewage farm.

The River Avon above the Rugby High Level sewage farm appeared to be in a fairly good condition, and there was no perceptible difference in the river below the points of discharge into it of the effluents. It should be stated that the effluent from the Rugby Low Level sewage farm joins the river some two miles above the High Level farm effluent outfall.

The River Cam at the time of the visits to the Cambridge sewage farm shewed no very evident signs of pollution either above or below the effluent outfalls. On one occasion, however, it was observed that some gas lime had been accidentally allowed to enter the river (see Part IV., Engineering and Practical Report).

The River Wandle, which appeared to be in a fairly satisfactory condition, received the effluent from the Beddington (Croydon) sewage farm and showed no obvious signs of deterioration in consequence.

The River Blackwater above the Aldershot Camp effluent outfalls was not in a satisfactory state, but the discharge of the effluents into it did not appear materially to alter its quality (*Cf.* page 58).

The Sinderland Brook shewed obvious signs of pollution above the Altrincham sewage farm effluent outfalls, and below the effluent outfalls was in a seemingly worse condition. But it is to be noted that the brook above the sewage farm outfalls is polluted to a considerable extent by tannery refuse and storm overflow liquid.

The Anstey Brook and Chaffinch Beck above the effluent outfalls at Leicester and South Norwood respectively appeared to be in a fairly satisfactory condition. Lower down, notwithstanding the entrance of the relatively large volume of Leicester and South Norwood effluents into the above brooks, the water shewed no visible signs of objectionable fouling.

It needs to be remembered that it is always difficult to assign the unsatisfactory condition of a river to any one cause. Not uncommonly there are a number of factors at work, of which the access of the effluent need not necessarily be the most objectionable.

16. *Number of Years Farm had been in operation before* 1900.

Beddington (Croydon)	39 years	Sludge disposed of on the farm.
South Norwood	36 „	Sludge disposed of on the farm.
Aldershot Camp	36 „	Sludge disposed of on the farm.
Rugby	33 „	Sludge partially disposed of on the farm.
Altrincham	30 „	Sludge disposed of on the farm.
Nottingham	19½ „	Sludge disposed of on the farm.
Leicester	9 „	Sludge partially disposed of on the farm.
Cambridge (systematic working)	5 „	Sludge disposed of on the farm.

Excluding Leicester and Cambridge, it will be observed that the remaining six farms have been in operation for from 19½ to 39 years (average about 32 years). It is important to note this fact in comparing land with artificial processes of sewage treatment. Moreover, some of these farms have throughout the whole period of their working disposed on their own land of all the sludge produced as a result of the sewage treatment. Indeed, making allowance for the difference in superficial area, the initial cost of construction, the depreciation and the working costs taken in conjunction are seemingly

less in the case of land than with artificial processes of sewage treatment; and, further, land, worked as a sewage farm, is always a tangible and usually an easily realisable asset.

Artificial processes have not been in operation for a sufficiently long period to warrant a critical computation being made as to their working cost. Existing calculations are necessarily of a somewhat speculative nature. While it is abundantly proved that land of suitable sort, given good management, will continue to purify sewage to a reasonable extent for long periods, with possible increase of efficiency and probable gain in market value as time goes on, the life history of bacteria-beds is still in some degree a matter for conjecture. Despite the advantages in particular, if not in general, cases of artificial (bacteria-bed) processes, we think that in the above respects the use of land for purifying sewage stands on a sound basis. We are well aware that in certain cases the treatment of sewage on land is either practically impossible or leads to such unsatisfactory results as to be undesirable, but this fact in no way invalidates the truth of the foregoing general statements.

Summary of the Foregoing Particulars.

The different sewage farms will be considered in the order of the volume of sewage treated per acre per 24 hours on the year's working of the whole of the irrigable area.

Cambridge Sewage Farm.

A reference to the foregoing diagrams will make it clear that in many respects Cambridge Sewage Farm stands in a class by itself. It treats the sewage of 675 persons per acre; no less than 121,600 gallons of sewage per acre per 24 hours being actually treated at one time, and 30,400 gallons per acre per 24 hours on the year's working (total irrigable area).* The sewage (mainly domestic) is, however, rather a weak one, and the farm does not deal with very much storm water. The soil (sandy loam, overlying gravel and sand) is well suited for sewage purification processes. The method of treatment is by filtration. About one-quarter of the total irrigable area is being actually sewaged at one time.

Altrincham Sewage Farm.

Altrincham Sewage Farm treats the sewage of 514 persons per acre; 46,000 gallons of sewage per acre per 24 hours at one time; and 23,000 gallons per acre per 24 hours on the year's working (total irrigable area). The sewage (domestic) is weak, and the farm deals with very little storm water. The outstanding feature here is the large volume of sewage being treated per acre on peaty soil, lying upon sand mixed with a little gravel. The method of treatment is by filtration. About one-half of the total irrigable area is being actually sewaged at one time.

Nottingham Sewage Farm.

Nottingham Sewage Farm treats the sewage of 397 persons per acre; 23,300 gallons of sewage per acre per 24 hours at one time and 10,750 gallons per acre per 24 hours on the year's working (total irrigable area). The sewage (four-sevenths domestic, three-sevenths trade refuse) is strong, but the farm deals with very little storm water. The soil (light sandy loam and gravel overlying gravel and sand) is admirably adapted for sewage

* The figures (a) 121,600, and (b) 30,400, are arrived at by dividing the dry weather flow of sewage by (a) the average area irrigated at one time ("working" area), and (b) by the total irrigable area ("working and 'resting" areas together).

purification purposes. The method of treatment is by filtration. About one-half of the total irrigable area is being actually sewaged at one time.

Beddington (Croydon) Sewage Farm.

Beddington (Croydon) Sewage Farm treats the sewage of 238 persons per acre; 57,100 gallons of sewage per acre per 24 hours at one time; and 9,500 gallons per acre per 24 hours on the year's working (total irrigable area). The sewage (mainly domestic) is of medium strength chemically. The soil (gravelly loam, over gravel and sand) is well suited for purifying sewage, but the method of treatment is by combined surface irrigation and filtration. About one-sixth of the total irrigable area is being actually sewaged at one time. The chief points of interest are the large volume of sewage being treated per acre per 24 hours and also (but to a less extent) per acre per annum on a sewage farm worked mainly as a surface irrigation farm; further, the relatively small area on the average under sewage at one time; lastly, the fact that all the storm water reaching the sewers is dealt with on the farm, there being no storm overflows.

Rugby Sewage Farm.

Rugby Sewage Farm treats the sewage of 171 persons per acre; 42,800 gallons of sewage per acre per 24 hours at one time; and 8,500 gallons per acre per 24 hours on the year's working (total irrigable area). The sewage (mainly domestic) is strong. The soil is heavy loam overlying stiff clay. The method of treatment is surface irrigation combined with some filtration. About one-fifth of the total irrigable area is actually sewaged at one time. The points of note are the somewhat large volume of strong sewage treated per acre per 24 hours and per acre per annum by surface irrigation (for the most part) on a heavy loam overlying stiff clay. Moreover, a large proportion of the storm water is treated on the farm.

Aldershot Camp Sewage Farm.

Aldershot Camp Farm treats the sewage of 166 persons per acre; 25,000 gallons of sewage per acre per 24 hours at one time; and 8,300 gallons per acre per 24 hours on the year's working (total irrigable area). The sewage (purely domestic) is very strong, but very little storm water gains access to the sewers. The soil and subsoil are sand. The method of treatment is filtration. About one-third of the total irrigable area is on the average under sewage at one time. On the year's working Aldershot Camp farm was treating a considerably smaller volume of sewage per acre than the other three filtration farms (Cambridge, Altrincham and Nottingham).

Leicester Sewage Farm.

Leicester Sewage Farm treats the sewage of 146 persons per acre; 21,500 gallons per acre per 24 hours at one time, and 5,370 gallons per acre per 24 hours on the year's working (total irrigable area). The sewage (three-fourths domestic, one quarter trade refuse) is of medium strength, and the farm does not deal with very much storm water. The soil is stiff clayey soil overlying dense clay. The method of treatment is surface irrigation with some filtration. About one-quarter of the total irrigable area is being actually sewaged at one time.

South Norwood Sewage Farm.

South Norwood Farm treats the sewage of 138 persons per acre; 12,000 gallons per acre per 24 hours at one time; and 4,000 gallons per acre per 24 hours on the year's working (total irrigable area). The sewage (purely domestic) is rather weak chemically. The soil is a somewhat lightened clay soil resting on London Clay. The method of treatment is chiefly surface irrigation. About one-third of the total irrigable area is actually sewaged at one time. South Norwood stands last among the above eight sewage farms as regards the volume of sewage treated per acre; but it is important to note that all the storm water reaching the sewers is dealt with on the farm, there being no storm overflows.

Before passing on to a description of the practical, meteorological, and other observations carried out at each of the sewage farms, a short summary may be given of the work done by the Rivers Pollution Commission of 1868.

SECTION III.

SHORT SUMMARY OF THE WORK DONE BY THE RIVERS POLLUTION COMMISSION OF 1868 ON THE LAND TREATMENT OF SEWAGE; together with a brief reference to the results obtained by the 1857-65 Commission, etc.

An admirably clear and concise historical summary with regard (1) to the disposal of water-borne sewage in this country during the last century, and (2) to the main objects of this disposal at different periods of the century, was given by Mr. Adrian in his evidence before the present Commission (vol. II., pp. 1-14). In this evidence he enumerates the various sanitary Commissions which have sat from time to time, and describes shortly the results arrived at by these Commissions, together with the bearing of those results and the recommendations arising from them upon the present state of the law with regard to sewage.

The first Sewage Commission proper was appointed in 1857, its third and last report being issued in 1865. We understand that the present rules of the Local Government Board with respect to sewage disposal are based generally upon the Report of this Commission.

We cannot do better here than quote from a few of the replies given by Mr. Adrian in evidence, referring the reader to this evidence as a whole. He subdivides the last century from 1842 onwards into three periods, viz.: (1) 1842-1857, when the primary aim was to secure the prompt removal of sewage from the neighbourhood of dwellings; (2) 1858-1870, which was characterised by the abandonment of the notion of possible injury to health as a consequence of irrigation of land by sewage, and by the growth of the belief in the ideal system of sewage disposal as being that which should aim at its profitable utilization by direct application to land, and should thus facilitate the protection of rivers from contamination; (3) the period from 1870 up to the present time, with the dominant idea that the prevention of the pollution of streams is an indispensable requisite of every system of sewage disposal which can lay claim to efficiency. Adrian, Q. 6. Q. 7. Q. 8.

One of the conclusions in the preliminary Report of the 1857 Commission was that the application of the whole sewage to land was not, when conducted with moderate care, productive of nuisance or injury to health. In their final Report, published in 1865, the Commissioners say: "The right "way to dispose of town sewage is to apply it continuously to land, and it "is only by such application that the pollution of rivers can be avoided." Q. 37. Q. 52.

Work of the Rivers Pollution Commission.

In any reference to sewage purification by land, the classical work of the Rivers Pollution Commission of 1868 demands special attention. After detailing the results of various laboratory experiments on the filtration of sewage through large glass tubes filled with different kinds of soil, the conclusion is drawn (*Vol.* I., *First Report*, *p.* 69) that:—

> "The cleansing power of a soil seems to be more closely connected "with physical condition, as regards porosity and fineness of division, "than with its chemical composition."
>
> Again, " . . . . . Our experiments also appear to show "that if the soil be not overdosed with sewage, it will retain its "efficiency for a long, if not for an unlimited period of time, and its "pores will not become clogged up."

This view, brought forward fully thirty years ago, has since been amply substantiated.

At the time when the Rivers Pollution Commission issued their Reports, little was known about bacteria and their action. But the following sentences are of peculiar interest, giving as they do, in a few words, the opinions held at the time by the Commissioners with regard to the theory of sewage purification.

Vol. 1, *First Report, p.* 70 :—

> " From all these experiments, then, it appears that the action of the " filter must not be considered as merely mechanical. The process " carried on in it is also chemical. Filtration, properly conducted, " results in the oxidation and transformation of offensive organic " substances in solution, as well as in the mere mechanical separation " of the suspended solid matters which, when in motion, sewage " conveys with it."

Again, in the section dealing with intermittent filtration (*Vol.* 1, *First Report, p.* 64) :—

> " These experiments also show that the process of purification is " essentially one of oxidation, the organic matter being, to a large " extent, converted into carbonic acid, water and nitric acid."

Sewage purification was thus regarded by them not merely as a mechanical process, but as a process of *direct* oxidation of organic matter.

The Rivers Pollution Commission examined the process of land purification of sewage by surface irrigation (combined in a few instances with filtration through the soil) at about a dozen different sewage farms. The observations at the Croydon (Beddington) and South Norwood farms extended over a year, and embraced fully 30 chemical analyses from either place, but only a few analyses in each case were made of effluents from the various other farms. Speaking generally, the results obtained were fair to good, the purification, of course, varying with the different types of soil. After contrasting the degree of purification at different seasons of the year, the Commissioners conclude :—

Vol. 1, *First Report, p.* 89 :—

> " It follows therefore that the cleansing of sewage is, in the absence " of actual frost, less dependent upon season than upon the quality " (*i.e.*, strength) of the sewage itself."

It is interesting, further, to note with regard to the Beddington Farm that :

Vol. 1, *First Report, p.* 88 :—

> " Only on one occasion (out of 27 analyses extending over a " year) was the effluent water discharged in a somewhat unsatisfac- " tory condition. On all other occasions the organic carbon and " nitrogen were present in proportions considerably below those " necessary to render the effluent water an offensive addition to " a stream at any season of the year."

Two further quotations may be given here, the first one being a comparison of downward intermittent filtration with irrigation.

Vol. 1., *First Report, p.* 96 :—

> " In round numbers it may be said that, on the average, the " processes of downward intermittent filtration and irrigation " remove from the soluble constituents of sewage (as measured by " organic carbon and nitrogen) twice as much polluting matter as that " got rid of by the processes of chemical treatment and of upward " filtration. Looking only to purity of effluent water it would be " difficult to decide between downward intermittent filtration on the " one hand and irrigation on the other, but there are obvious reasons " why the latter must, in all but very rare and exceptional instances, " be preferred on economical grounds. Intermittent filtration is a

"costly process with no possibility of any return, whilst irrigation, "although it may in the first instance require a large outlay of "capital, affords a hopeful prospect of a return for the capital invested."

Vol. 1. *Second Report, p.* 20 :—

"Irrigation is the only process of cleansing sewage which has stood "the test of experience, and unless it is extensively adopted, there is "but little hope of any substantial improvement in our sewage-polluted "rivers."

These conclusions are of the highest interest, giving as they do the best views of thirty years ago upon the subject.

Standards of Purity recommended by the Rivers Pollution Commission.

These apply to effluents generally, and not merely to land effluents.

Vol. 1, *Fifth Report, p.* 49 :—

"We now recommend, therefore, that, with the exceptions already "mentioned in reference to standards (d) and (e),* the following "liquids be deemed polluting and inadmissible into any stream :—

(a) "Any liquid which has not been subjected to perfect rest in "subsidence ponds of sufficient size for a period of at least six hours, "*or* which, having been so subjected to subsidence, contains in "*suspension* more than one part by weight of dry organic matter in "100,000 parts by weight of the liquid, *or* which, not having been so "subjected to subsidence, contains *in suspension* more than three parts "by weight of dry mineral matter, or one part by weight of dry "organic matter in 100,000 parts by weight of the liquid.

(b) "Any liquid containing, *in solution*, more than two parts by "weight of organic carbon or ·3 part by weight of organic nitrogen in "100,000 parts by weight.

(c) "Any liquid which shall exhibit by daylight a distinct colour "when a stratum of it one inch deep is placed in a white porcelain or "earthenware vessel.

(d) "Any liquid which contains, *in solution*, in 100,000 parts by "weight, more than two parts by weight of any metal except calcium, "magnesium, potassium, and sodium.

(e) "Any liquid which, in 100,000 parts by weight, contains, *whether* "*in solution or suspension*, in chemical combination or otherwise, more "than ·05 part by weight of metallic arsenic.

(f) "Any liquid which, after acidification with sulphuric acid, con-"tains, in 100,000 parts by weight, more than one part by weight of "free chlorine."

(g) "Any liquid which contains, in 100,000 parts by weight, more "than one part by weight of sulphur, in the condition either of "sulphuretted hydrogen or of a soluble sulphuret.

(h) "Any liquid possessing an acidity greater than that which is "produced by adding two parts by weight of real muriatic acid to "1,000 parts by weight of distilled water.

(i) "Any liquid possessing an alkalinity greater than that produced "by adding one part by weight of dry caustic soda to 1,000 parts by "weight of distilled water.

(k) "Any liquid exhibiting a film of petroleum or hydrocarbon oil "upon its surface, or containing in suspension, in 100,000 parts, more "than ·05 part of such oil."

---

* *Vol.* 1, *Fifth Report, p.* 45.—"The occurrence of arsenic in colliery water in so large a propor-"tion (0·05 part metallic arsenic in 100,000 parts water) 'appears to be quite exceptional, and, as "there are no known practicable means of removing this ingredient from water, especially if the "latter be, like that discharged from the Dowlais coal-washing floor, non-ferruginous, we "recommend that colliery water and mine waters generally be exempted from the operation of "standards (d) and (e)."

This short summary of the work of former Commissions may be fitly concluded by a few more extracts from Mr. Adrian's evidence.

An important conclusion with regard to the purification of sewage by broad irrigation, from the Report of the Thames Commission of 1882-84, also deserves notice here :—

Adrian, Q. 74.

Par. 206. "The evidence shows that there can be no doubt as to "the efficient purification when the works (of a sewage farm) are "proper and the management is careful. This, indeed, is sufficiently "proved by the fact that the effluent under these conditions is "considered suitable to be allowed to flow into running streams from "which water supply is drawn."

This conclusion, so far as drinking water streams are concerned, has not been borne out by the bacteriological work done for the present Commission. (Cf. Section V. of this Report.)

With regard to the genesis and growth of the present laws regulating sewage disposal, Mr. Adrian states :—

Q. 80.

"The Public Health Act, 1875, being a consolidating Act, "contains provisions which, if traced to their origin, are seen to "belong to the legislation of some one or other of the three periods "already mentioned, and reflect, even in their present context, the "prevailing ideas and aims of the period. Thus, when we attempt a "broad classification of the law by reference to the powers which it "confers, and the restrictions it imposes, we observe that, although "the powers as now used may be made to subserve the modern "purpose of river protection, they are fundamentally the outcome of a "system of utilization, or of the profitable application of sewage."

Q. 104.

"When the Local Government Board came into existence, one of "the most important methods of sewage treatment, viz., intermittent "downward filtration, was as yet a novelty. The other method of "land treatment, viz., by broad irrigation, seems to have been "favoured as much as possible when circumstances admitted."

Q. 107.

"The present practice of the Local Government Board, I think, "dates from the investigation of the complaints which led to the "appointment of the Metropolitan Sewage Commission. Since the pub-"lication of the Report of that Commission the Board have regarded "themselves as justified, save in exceptional cases, in requiring that "any scheme of sewage disposal for which money is to be borrowed "with their sanction should provide for the application of the sewage "or effluent to an adequate area of suitable land before its discharge "into a stream. At the same time the Board have been fully "prepared to recognise improvements in chemical treatment; and "this is shown in the rules which, after much consideration, were "adopted in 1890."

SECTION IV.

Practical and Meteorological Observations.

Together with Notes as regards the Collection of Samples, and the routine work carried out during the visits to each of the Sewage Farms.

Different times of the Year chosen for the visits to each of the Farms.

As far as possible, different times of year were chosen for the visits to each of the farms selected for observation, with a view to (1) ascertaining, if possible, to what degree the effluents were affected by seasonal variations in temperature, rainfall, &c., and (2) obtaining a fair idea of the working of the farm throughout the year. It is perhaps hardly necessary to add that a considerable element of uncertainty existed as to the prospective meteorological conditions. On more than one occasion a spell of cold weather occurring in the warmer months of the year, and conversely a period of warm weather during the cold season, upset our anticipations to a considerable extent.

Differences of air temperature during the visits to each of the farms.

As regards the farms which were visited more than once, it will be observed from the following table that, with the exception of South Norwood (which was only visited in cold weather), and Altrincham (visited twice in the late spring), the differences in air temperature were on the whole well marked :—

Name of Farm.	Number of Visit.	Mean daily Temperature.	Mean daily Maximum Temperature.	Mean daily Minimum Temperature.	Mean daily Rainfall.	Time of Year.
Nottingham - -	1st visit -	1·1°C.(34°F.)	3·8°C.(39°F.)	–1·1 C.(30°F.)	·03″	December.
„ - -	2nd „ -	17·2°C.(63°F.)	22·7°C.(73°F.)	12·2°C.(54°F.)	·19″	July and August.
Aldershot Camp -	1st „ -	3·8°C.(39°F.)	9.4°C.(49°F.)	–1·6°C.(29°F.)	·05″	March.
„ -	2nd „ -	13·3°C.(56°F.)	20·5°C.(69°F.)	6·6°C.(44°F.)	·02″	May and June.
„ -	3rd „ -	17·2°C.(63°F.)	25·5°C.(78°F.)	9·4°C.(49°F.)	·06″	June and July.
Cambridge - -	1st „ -	2·7°C.(37°F.)	5·0°C.(41°F.)	0·5°C.(33°F.)	·02″	Jan. and Feb.
Altrincham - -	1st „ -	10·0°C.(50°F.)	16·1°C.(61°F.)	3·8°C.(39°F.)	·07″	April and March.
, -	2nd „ -	11·6°C.(53°F.)	18·8°C.(66°F.)	4·4°C.(40°F.)	·02″	April and March.
Beddington - -	1st „ -	3·8°C.(39°F.)	8·3°C.(47°F.)	0·0°C.(32°F.)	·10″	February.
„ - -	2nd „ -	10·0°C.(50°F.)	16·1°C.(61°F.)	4·4°C.(40°F.)	·03″	October.
„ - -	3rd „ -	10·0°C.(50°F.)	13·8°C.(57°F.)	6·6°C.(44°F.)	·07″	November.
Leicester - -	1st „ -	6·6°C.(44°F.)	10·5°C.(51°F.)	3·3°C.(38°F.)	·04″	November.
„ - -	2nd „ -	14·4°C.(58°F.)	20·5°C.(69°F.)	8·3°C.(47°F.)	·05″	August and Sept.
„ - -	3rd „ -	13·8°C.(57°F.)	21·1°C.(70°F.)	7·2°C.(45°F.)	·01″	September.
South Norwood -	1st „ -	3·8°C.(39°F.)	6·6°C.(44°F.)	1·1°C.(34°F.)	·06″	January.
„ -	2nd „ -	6·6°C.(44°F.)	10·0°C.(50°F.)	2·7°C.(37°F.)	·09″	November.
„ -	3rd „ -	7·2°C.(45°F.)	10·5°C.(51°F.)	4·4°C.(40°F.)	·06″	November.
Rugby - - -	1st „ -	13·8°C.(57°F.)	19·4°C.(67°F.)	8·3°C.(47°F.)	·06″	June.
„ -	2nd „ -	4·4°C.(40°F.)	8·3°C.(47°F.)	1·1°C.(34°F.)	·05″	Feb. and March.

It will further be noticed that the mean daily rainfall varied considerably in the case of the majority of the farms.

Influence of the temperature of the air on the temperature of the effluents.

That the influence of the air temperature on the temperature of the effluents resulting from surface irrigation is very marked is shown by comparison between the curves of air, sewage, and effluent temperatures in the case of Beddington and South Norwood; the temperature of the effluents varied *pari passu* with the changes in atmospheric temperature.

It will be convenient here to refer briefly to the temperatures of samples which—as mentioned elsewhere—were taken in conjunction with the air temperature at the time of drawing. The appended table gives the average temperatures of sewage and effluent samples, drawn at each visit to the farms :—

Name of Farm.	Number of Visit.	Average Sewage Temperature.	Average Effluent Temperature.	Time of Year.
Altrincham - -	1st visit - -	9·4° C. (49° F.)	10·0° C. (50° F.)	April and May.
„ -	2nd „ - -	12·2° C. (54° F.)	9·4° C. (49° F.)	April and May.
Aldershot Camp -	1st „ - -	7·2° C. (45° F.)	6·6° C. (44° F.)	March.
„ „ -	2nd „ - -	15·0° C. (59° F.)	12·2° C. (54° F.)	May and June.
„ „ -	3rd „ - -	19·4° C. (67° F.)	14·4° C. (58° F.)	June and July.
„ „ -	4th „ - -	12·7° C. (55° F.)	10·0° C. (50° F.)	October.
Beddington- -	1st „ - -	9·4° C. (49° F.)	5·5° C. (42° F.)	February.
„ - -	2nd „ - -	15·0° C. (59° F.)	12·7° C. (55° F.)	October.
„ - -	3rd „ - -	14·4° C. (58° F.)	12·2° C. (54° F.)	November.
Cambridge - -	1st „ - -	3·3° C. (38° F.)	3·8° C. (39° F.)	Jan. and Feb.
Leicester - -	1st „ - -	13·3° C. (56° F.)	8·8° C. (48° F.)	November.
„ - -	2nd „ - -	16·6° C. (62° F.)	17·7° C. (64° F.)	August and Sept.
„ - -	3rd „ - -	17·2° C. (63° F.)	16·1° C. (61° F.)	September.
„ - -	4th „ - -	17·7° C. (64° F.)	15·5° C. (60° F.)	October.
Nottingham -	1st „ - -	15·0° C. (59° F.)	9·4° C. (49° F.)	December.
„ -	2nd „ - -	18·3° C. (65° F.)	11·6° C. (53° F.)	July and August.
„ -	3rd „ - -	20·0° C. (68° F.)	13·3° C. (56° F.)	September.
Rugby- - -	1st „ - -	13·8° C. (57° F.)	16·6° C. (62° F.)	June.
„ - -	2nd „ - -	7·2° C. (45° F.)	5·0° C. (41° F.)	February and March.
South Norwood -	1st „ - -	7·7° C. (46° F.)	5·0° C. (41° F.)	January.
„ „ -	2nd „ - -	8·3° C. (47° F.)	8·3° C. (47° F.)	November.
„ „ -	3rd „ - -	10·0° C. (50° F.)	9·4° C. (49° F.)	Nov., Dec. and Jan.

In connection with the filtration farms—Nottingham, Aldershot Camp, Altrincham, and Cambridge—it is well to bear in mind the fact that greater variations occur in "chance" samples from different areas of land than is the case when the temperatures are taken daily from the same place. This may probably be accounted for by the fact that the drains frequently vary in depth on different plots of land, and are usually shallowest at the end furthest from the effluent outfalls, hence a different temperature is to be anticipated from effluents drawn at the high and low levels, respectively. The surface irrigation effluents tend to vary in temperature almost from hour to hour according to the temperature of the air at the time they are drawn. It must also be remembered that the above tabulated temperatures extend over three years, while the systematic observations of the temperature of air, sewage and effluent were taken over a period of one year only. In Part IV. (Engineering Report) this matter is dealt with in more detail, but it will not be out of place to include here the diagram illustrating the above facts (*see* diagram 9).

In conclusion, the temperatures of the various samples show (1) that the daily temperature of the effluents from filtration farms is remarkably uniform, and bears only an indirect relation to the prevailing atmospheric temperature, notwithstanding that its monthly and seasonal mean temperature naturally varies to a greater extent; and (2) that the surface irrigation farm effluents show considerable fluctuations in temperature within a comparatively short space of time, and vary more or less directly according to the temperature of the air.

Description of farms, with illustrative plans, notes on samples, systematic, practical and meteorological records, etc.

In Part IV. (Engineering Report) a full description is given of each farm, embodying many items of interest:—(1) in connection with the different sewerage systems, (2) as regards the several methods of irrigation in use, and (3) in respect of other matters which appeared to have a definite bearing on the purification of the sewage.

A plan is given of each of the eight farms, viz., Aldershot Camp, Altrincham, Beddington, Cambridge, Leicester, Nottingham, Rugby and South Norwood, and other explanatory plans and sections are also given where necessary.

All samples drawn were numbered, and notes were made on the spot with reference to conditions which seemed likely to affect the analyses. These notes are given in Part IV. (Engineering Report) in tabular form under the following heads:—

Table of all samples drawn at each farm shewing:—

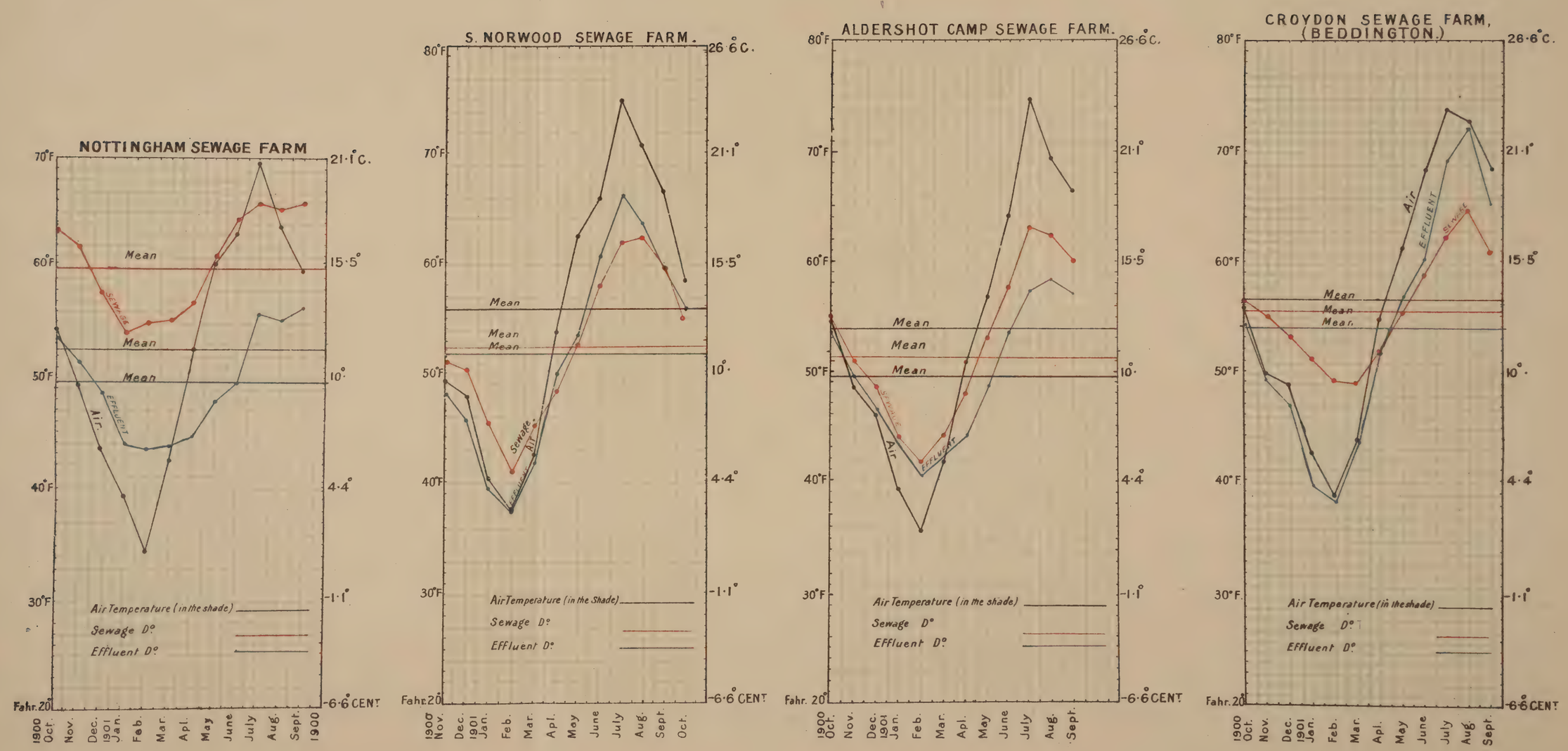
(1) Number of sample.
(2) Date of drawing sample.
(3) Time of day.
(4) Rainfall (day previous to drawing sample).
(5) Rainfall (day of drawing sample).
(6) Atmospheric temperature (time of drawing sample).
(7) Temperature of sample.
(8) Maximum temperature during the 24 hours.
(9) Minimum temperature during the 24 hours.
(10) Humidity.
(11) Dissolved oxygen in sample (approximate).
(12) Brief description of sample.
(13) Remarks.

Table of all samples of effluents drawn at each farm shewing:—

(1) Number of sample.
(2) Number of times the sewage had been passed over or through the soil.
(3) Area of plot or plots sewaged at the time of drawing the sample.
(4) Length of time these plots had been sewaged previously to drawing sample.
(5) Nature of crops grown on plots.

Diagram 9.

Temperatures.



NOTE. The horizontal black red & blue lines give the mean Temperatures for the year of the air sewage & effluent respectively.

3311. 11. 02.

Table of comparative samples.
Table of corresponding samples.
Table of sewage samples.

In addition to the above, further notes were made where it was deemed necessary, and these will be found under the heading of "Additional Notes on Samples."

At each of the eight farms kept under systematic observation, the maximum and minimum temperatures, the rainfall, and (at a later stage) the humidity of the air were recorded daily, and are given in chart form. It was impossible at the commencement of the investigation to foresee how far these meteorological observations would be of use when studied in conjunction with the chemical and bacteriological results, but obviously it was of great importance to obtain the records. That it is not always easy to interpret the individual, if not general, chemical and bacteriological results in relation to the meteorological records does not mean that the collection of meteorological data is of small value.

Collection of samples. The sampling of sewage, of effluents, and of mixed river water and effluent.

All samples of sewage and effluent (excepting the experimental effluents) were taken during the ordinary working of the farms, *i.e.*, the sewage was not during the visits spread over either a larger or a smaller area of land than usual, the conditions in all respects being normal.

The range of time during the day in which samples of sewage and effluents were drawn is given in the following table, the farms being arranged in alphabetical order :—

Name of Farm.	Sewage Samples.	Effluent Samples.
Aldershot Camp -	9.45 a.m. to 2 p.m.	10 a.m. to 4.30 p.m.
Altrincham - -	10.15 a.m. to 12 noon .	10.45 a.m. to 2.30 p.m.
Beddington - -	10.30 a.m. to 3 p.m.	11 a.m. to 5.15 p.m.
Cambridge - -	11.15 a.m. to 2.30 p.m.	11.15 a.m. to 4.45 p.m.
Leicester - -	10.30 a.m. to 12.30 p.m.	11.15 a.m. to 3.15 p.m.
Nottingham- -	11.35 a.m. to 3 p.m.	11.30 a.m. to 4 p.m.
Rugby- - -	10.30 a.m. to 4 p.m.	10.45 a.m. to 5 p.m.
South Norwood -	11 a.m. to 3.45 p.m.	10.30 a.m. to 5.15 p.m,

It will be seen from the above table that the samples show a fair range of time as regards drawing, and that therefore they would presumably be likely to include effluents resulting from the strongest sewage.

It was necessary in certain cases to draw and despatch the samples sooner than would otherwise have been the case, in order to ensure their early arrival at the laboratories.

The sampling of sewage.

The sampling of sewage—"chance" samples—from carriers on a farm is a matter of difficulty, more especially when the sewage is crude and has not undergone any previous treatment. The method adopted in these cases was carefully to fill the sample bottle at about one-half the depth of sewage in the carrier adjacent to the point where this sewage flowed on to the land, avoiding stirring up sediment.

In the case of very long carriers, a considerable amount of sedimentation frequently takes place, as in a settling tank, and consequently a plot sewaged at the end of such a carrier receives less than its fair proportion of suspended matter.

The drawing of sewage samples after passing through settling tanks presented less difficulty, the settled tank liquor as a rule being fairly uniform in quality. As regards sewages where manufacturing refuse occurs, the character of the sewage frequently changes very suddenly throughout the day, and a sample taken at a certain time one day may differ considerably from a sample taken at precisely the same time on another occasion.

The sampling of effluents.

The drawing of "corresponding samples," *i.e.*, of samples intended to shew the amount of purification effected in the various stages, presented many difficulties, and these samples can therefore only be regarded as corresponding approximately.

For example, in the case of a field sewaged after a period of rest, if a sample is taken of (*a*) the on-flowing sewage and afterwards (*b*) the first effluent issuing from the drains (on filtration farms), or coming off the bottom of the field (on surface irrigation farms), it is doubtful whether the two samples really correspond. The reason for this appears to be that a very large amount of sewage may be (and usually is) absorbed by the soil before any effluent appears, this amount depending upon the nature of the soil, the time the land has been resting, volume of sewage applied, good distribution or otherwise, crops, etc., in addition to a large number of variable factors, such as temperature, rainfall, humidity, etc. Further, in the case of a filtration farm, sudden rainfall with a humid atmosphere may cause the effluent to percolate to the drains very much faster than would be the case with a dry soil, drying wind and high temperature, and this applies with even greater force to effluents from surface irrigation farms, where a relatively greater area of evaporation is usually exposed in proportion to the volume of sewage.

It will thus be seen that care had to be exercised in the collection of these "corresponding" samples, and all that can be said is that the sample of effluent was collected at such a time after the sewage sample as to represent, as far as possible, the degree of purification effected on the sewage by its passage over or through the soil.

The drawing of filtration effluents.

In the case of the filtration farms visited (Nottingham, Cambridge, Aldershot Camp, and Altrincham) the effluent only passed through the soil once, immediately flowing off by the underdrains to the main effluent channel.

At the above-mentioned farms the *final effluents* were obtained from the underdrains of individual plots, in order to ascertain the nature of the effluents from different crops under sewage. The mixtures of these several effluents (*termed general or combined effluents*) were taken from the main (or common) effluent channels. It is worthy of note in this connection that, when the whole of the several effluents from different plots of land leave the farm by a common channel, if one of these separate effluents should chance to be unsatisfactory, it may affect the general or combined effluent prejudicially. Taking a case in point, where the separate effluents are, generally speaking, of good quality, a very slight leakage of imperfectly-purified sewage into the common effluent channel, brought about by rat holes or other causes, may affect the quality of the general or combined effluent to a considerable extent.

The drawing of surface irrigation effluents.

With regard to samples from the surface irrigation farms (South Norwood, Leicester, Beddington, and Rugby), when the sewage was run over more than one plot of land, samples were taken from the foot of each plot, *i.e.*, first, second, third field effluents, etc., according to the field from which the effluent was drawn; the effluent being taken from the "pick-up" carriers at the foot of the plots, to ensure fair average samples as far as possible.

Where both surface and filtration effluents occurred on the same farm, samples were taken of each.

The drawing of samples of mixed river water and effluent.

The samples of mixed river water and effluent were taken as far as possible at points where the two liquids appeared likely to have become thoroughly mixed together.

In several instances, however, effluent outfalls from other sewage farms, or other factors, precluded the taking of samples low down on the stream, and for this reason mixtures of river water and effluent had to be taken nearer to the effluent outfall than was desirable, having regard to the fact that effluents flowing into rivers and streams may, under certain circumstances, flow for some considerable distance without becoming effectually mingled.

Definition of terms.

At this stage it may be of advantage to summarise very briefly what is meant by first field effluent; second field effluent; comparative samples; "corresponding" samples; final effluents; and general or combined effluents.

First field Effluents :—The effluents from sewage after having been passed over (or through) one plot of land.

Second field effluents :—The effluents from sewage after having been passed over (or through) two plots of land.

Neither of these are to be regarded as finally-treated effluents unless so specified.

Comparative samples :—Samples collected from the same source under comparable conditions, except as regards time of drawing the sample. For instance, an effluent drawn on one day from a particular plot of land, "dosed" with a definite volume of sewage, is comparable with effluents derived from the same source on succeeding days, the conditions meanwhile remaining fairly constant.

"Corresponding" samples:—Effluents drawn at such a time after the application of the sewage to the land as fairly to represent the degree of purification effected on the sewage by its treatment on the land.

Final effluents :—As the name implies, these are finally-treated effluents by the particular process.

General or combined effluents.—Mixtures of two or more finally-treated effluents.

SECTION V.

Summary of Chemical Results and Conclusions.

The subject of the purification of sewage by land is so complex and involves so many factors that it is very difficult to give a satisfactory short summary of the chemical results of a long investigation on the subject. Those results are given in detail in the separate Reports, Tables of Analysis and Curves appertaining to each farm, and are more or less fully summarized in the *Conclusions* of the Chemical Report (Part II.), and to some extent shortly summarized in the *Joint Chemical and Bacteriological Conclusions* of this Report (Section VII.).

The process of purification of sewage on land is, as is well known, one depending ultimately on efficient oxidation—*i.e.*, on indirect oxidation by the oxygen of the air through the agency of nitrifying organisms. These organisms are of course active in the surface soil where the aeration is readily kept up, though aeration here must necessarily vary with the porosity and texture of the soil itself. It is obvious, therefore, that what is wanted in the soil and subsoil of a filtration farm is good aeration combined with as rapid filtration as is consistent with good purification: or, in other words, we require that in the soil and subsoil neither the aggregate number of particles per unit volume of soil nor the aggregate filtration surface exposed by those particles shall fall below or exceed certain limits. In order, therefore, to be able to form an approximate estimate of the purifying effect which any particular soil is likely to exercise upon a given sewage, we ought to know:—

(*a*) The volume and strength of the sewage.

(*b*) The quality of soil and subsoil as determined by mechanical analysis.

(*c*) If possible, the average rates of filtration through the soil and subsoil.

(*d*) It may also be desirable to determine the amount of lime or other chemical constituent of the soil.

A short description and comparison of the various soils and subsoils examined are given in Sub-section 13 of this Report, while the subject is treated in detail in the sectionof the Chemical Report which deals with Soils.

The appended Tables* (A) (B) and (C) on pages 52--55 show respectively:—

(A.) The average chemical composition of the different sewages treated on the eight principal farms under observation.

(B.) The average chemical composition of the different effluents.

(C.) The *approximate* percentage purification effected at each farm, as calculated by the reduction in (*a*) albuminoid nitrogen; (*b*) "oxygen absorbed" from permanganate.

The last table is given for the convenience of those who are in the habit of gauging purification in this way, but it must be remembered that the calculation is merely empirical, the organic matter in a purified effluent being totally different as regards fermentability from the organic matter in the original sewage.

In connection with these figures of analysis, the usefulness of estimating the *total nitrogen* in a sewage or effluent may just be referred to.

* For fuller details of analysis, see the separate Farm Reports and Tables.

Sewages.—The differences shown by the various sewages as regards organic strength and quality have already been dwelt upon sufficiently in Section II., Sub-section 11.

Effluents.—With respect to effluents, it will be observed that neither in this nor in the Chemical Report has any fixed chemical standard for effluents been specified. The reasons for not advancing a definite opinion upon this point in the meantime are discussed a little further on under the heading "Chemical Standards of Purity for Sewage Effluents," and also in that section of the Chemical Report which deals with the question of standards. At the same time it should be said here that in endeavouring to arrive at the quality of any particular effluent, or of the effluents generally from any one farm, the following points, among others, have been borne in mind :—

1. The smell of the effluent and its general appearance with regard to colour, solids in suspension, etc.
2. How the effluent would be judged (speaking approximately) by the Mersey and Irwell provisional standard as regards albuminoid nitrogen and "oxygen absorbed" from permanganate (but allowing to some extent for the "oxygen absorbed" being determined from strong permanganate at 80° F. and not from weak permanganate at 60° F.).*
3. Whether or not it withstood the incubator test.
4. The amount of dissolved oxygen present at the time of analysis† and the comparison of this with the quantity present when the sample was drawn, having regard here also to whether a surface irrigation or a filtration effluent was in question; further whether any oxygen remained after incubation either at atmospheric temperature or at a temperature of 26·7° C. (80° F.)
5. The amount of nitrate present, and how far that nitrate was reduced upon incubation.
6. The approximate ratio of oxidised (*i.e.*, nitric + nitrous) nitrogen to the albuminoid and to the total organic nitrogen, and also to the total unoxidized nitrogen.

The purification results at the different farms may be summarized as follows :—

1. Cambridge (*Filtration, mostly without cropping.*)

The Cambridge farm treats, on a good porous soil and subsoil, an exceptionally large volume of a somewhat weak domestic sewage, which however contains in the aggregate a very large quantity of organic matter—more than half as much again as the organic matter treated per acre at Nottingham (*cf.* diagrams 5 and 6, Section II., Subsection 11). The result is a dilute effluent which is usually from a chemical point of view good, and sometimes very good. At the same time the organic matter left in some of the less highly purified effluents is of a somewhat putrescible character, as judged by the incubator test, though there is nearly always enough nitrate present to keep the liquid inoffensive upon incubation. The number of particles‡ in unit weight of ignited soil and subsoil, taking the numbers at Nottingham as 100 in each case, are :—soil 75, subsoil 61. The relative calculated§ *internal* filtering area at Cambridge per unit of surface, down to the drains, works out to about three-quarters that at Nottingham, but depth for depth there is not a great deal of difference between the two, the drain pipes being laid deeper at Nottingham. The rate of filtration at Cambridge must be a medium rate, probably rather faster than that at Nottingham. If, therefore, the two farms were laid out in the same way, and treated the same sewage in equal volumes per acre, we should expect the results to be much the same, though probably with a slight balance in favour of Nottingham.

---

* *Cf.* Fourth Report of Royal Commission on Sewage Disposal, Vol. IV., Part V.—Report to the Commission by Dr. G. McGowan, Mr. R. B. Floris and Mr. R. S. Finlow on Methods of Chemical Analysis as applied to Sewage and Sewage Effluents.

† A fully aerated sample would contain roughly about 7 cubic centimetres of oxygen per litre, *i.e.*, 7 volumes of oxygen per 1,000 volumes of water.

‡ As already stated, these numbers of particles (in this and the other soils and subsoils) refer to the ignited soil or subsoil, and therefore take no account of particles of organic matter present.

§ This calculation is of necessity only an approximate one.

2. Altrincham (*Filtration, with cropping*).

Altrincham also treats a large volume of a weak domestic sewage, about three-fourths of the volume at Cambridge (*cf.* Diagram 6, Section II., Sub-section 11), but on a porous peaty soil, overlying sand admixed with a little gravel. We have not sufficient data to give either the relative amount of organic matter treated per acre, though this must be large, or the approximate relative internal filtering area of the Altrincham soil and subsoil down to the drains. The number of particles in unit weight of ignited soil (Nottingham = 100) is 157. The rate of filtration at Altrincham is probably fairly rapid. The result is an effluent which is on the whole fairly satisfactory chemically, but the farm had apparently rather too much to do at the time of our observations. As regards the treatment of large volumes of weak domestic sewage, Cambridge and Altrincham are more or less parallel; but in the nature of the soil and subsoil and in the depth to the drains the two differ materially.

3. Nottingham (*Filtration, with cropping*).

Nottingham treats, on an excellent loamy soil and gravelly subsoil, a medium volume of a rather strong sewage containing 40 per cent. of trade refuse, the aggregate organic matter treated per acre at Nottingham being about two-thirds that at Cambridge. The number of particles in unit weights of ignited soil and subsoil is here taken at 100 in each case, for the purpose of comparison with the soils and subsoils at other farms. The relative calculated internal filtering area down to the drains is about one-third greater than at Cambridge, and the rate of filtration is probably somewhat slow. The result of the treatment at Nottingham is an effluent of altogether exceptional quality, clear and sparkling, and approaching in the best samples within measureable distance, from a chemical point of view, of a drinking water.

4. Aldershot Camp (*Filtration, with cropping*).

At Aldershot Camp a medium volume of a very strong and highly ammoniacal sewage is treated on a relatively coarse sandy soil overlying a fine sandy subsoil containing a great deal of iron. The aggregate organic matter treated per acre is on the whole, perhaps, somewhat greater than at Nottingham (*cf.* Diagram 5, Section II., Sub-section 11), but there is no trade refuse mixed with the sewage. The average depth to the drains is about 3 feet 3 inches, and the rate of filtration through such a fine sandy subsoil must be rather slow. The numbers of particles in unit weights of ignited soil and subsoil (Nottingham = 100), are:—soil, 19; subsoil, 394. The relative calculated internal filtration surface area down to the drains is almost the same as that at Nottingham. The general result of the treatment at Aldershot is a highly nitrated effluent, still containing in some instances a considerable amount of organic matter, not much of which however is of a rapidly fermentable character, as judged by the incubator test, and the nitrate present is always much more than sufficient to keep the effluents from putrefying. They often contain, however, considerable quantities of very flocculent vegetable matter, coloured by oxide of iron, washed from the drain pipes.

It will be observed that, apart from texture, the conditions for the aeration of the soil and subsoil are the reverse at Aldershot Camp to what obtain at Nottingham and Cambridge, and are probably less favourable, for at the former we have a coarse sand resting upon very fine sand, while at the two latter a fine loam rests upon coarse sand and gravel.

5. Croydon, Beddington (*as a Filtration farm, with cropping*).

Although Beddington is primarily a surface irrigation farm, a portion of it is drained, and reference may therefore be made to that portion here. The soil and subsoil are, generally speaking, directly comparable in texture with those at Nottingham and Cambridge, though the Beddington subsoil is much the most stony of the three, The numbers of particles in unit weights of the ignited soil and subsoil (Nottingham = 100) are:—soil, 46; subsoil,

55. Taking the average depth down to the drains at 6 feet 6 inches, then the relative calculated internal filtration area per unit of surface is about four-fifths that at Nottingham. The rate of filtration must also be somewhat similar to the rates at Nottingham and Cambridge, though no doubt appreciably faster. The results of the analysis of the second field filtration effluents obtained in the special experiment (see Part II., Chemical Report on the Beddington Farm) show what a high degree of purification, chemically speaking, can be obtained by using Beddington as a filtration farm. The soil and subsoil being, however, distinctly coarser than those at Nottingham, would probably not produce (under exactly similar conditions) quite such good results as we have obtained at the latter place; on the other hand aeration would be easier at Beddington.

5a. Croydon, Beddington (*as a Surface Irrigation farm.*)

Since the surface soil at Beddington is about 15 inches deep, we are to a certain extent dealing here with a shallow filtration farm, with very good soil for the purpose of sewage purification. But with our present data it is impossible to say how much of the purification effected at Beddington is due to filtration through the top soil and how much to surface irrigation pure and simple. The sewage is practically a domestic one, of moderate strength —probably of about average strength. The volume of sewage treated per acre—exclusive of storm water—was very large for a surface irrigation farm, being only a little less than at Nottingham and a little more than at Rugby and Aldershot Camp, while the aggregate organic matter treated per acre was less than at Rugby (*see* diagrams 5 and 6, Section II., Sub-section 11). The variations in flow and the additional matter to be dealt with, owing to sudden influxes of storm water at Beddington, must add greatly to the difficulty of management. The analytical results of the final effluents show that the Beddington Farm, used for surface irrigation under the conditions detailed in the Engineering Report, is capable of producing a high-class effluent, and does so sometimes but not always, the inference being that the land had rather too much to do.*

6. Rugby High Level Farm (*Surface Irrigation on stiff soil with underdrains*).

Rugby was originally chosen as an example of a sewage farm with a heavy loam soil, *i.e.*, a soil midway between a light loam and a clay. We had very great difficulty in finding a suitable farm with this type of soil, and Rugby was ultimately fixed upon as being on the whole the most suitable. As will be seen, however, from a comparison of the mechanical analysis of the Rugby surface soil with those of Leicester and South Norwood, that at Rugby is apparently—contrary to expectation—more of a clay than the others. But gravel "pockets" occur in the subsoil at Rugby, and these must to some extent increase the purification by the filtration which takes place through them. The surface soil itself is about 10 inches deep and it overlies yellow clay, the average depth of the drains being about 3 feet 9 inches. The number of particles in unit weight of the ignited soil (Nottingham = 100) is 392.

The sewage at Rugby is domestic (some engine oil is present) and the volume treated there per acre is almost the same as at Aldershot Camp. The Rugby sewage is, however, not quite so strong organically, though it contains more suspended solids, and hence the aggregate organic matter treated per acre of irrigable area is rather less (*see* diagrams 5 and 6, Section II., Sub-section 11). Still, the amounts of sewage matter to be purified per acre in the two cases, in almost equal volumes of liquid, are sufficiently near to make a rough comparison of interest. At Aldershot Camp, as already seen, we have one filtration of the sewage through sand, with the production of a highly nitrated effluent. At Rugby, on the other hand, the effluent from half of the sewage, passed for the most part over† one (larger) plot of ground, is mixed with the

* Since the foregoing observations were made, some bacterial filters have been erected at Beddington, with a view to lessening the work laid upon the land.

† The temperature of the Rugby effluents indicated that they were mainly from surface irrigation.

other half of the sewage, and this mixture is run over a second (smaller) plot. the result being an effluent of quite a different character from that at Aldershot Camp, *i.e.*, much less highly nitrated, but at the same time containing less total nitrogen, less organic nitrogen, and less oxidizable matter generally. Whether this greater decrease in nitrogen is brought about wholly through greater absorption by plants (greater than is possible with filtration through cropped sandy soil), or partly also through the mutual decomposition of nitrate and ammonia by the agency of microbes, would be an interesting point to know.

The Rugby soil is thus capable of producing a very fair surface irrigation effluent of even composition, as was shown by the samples which were drawn and examined in spring; but the quality of the summer samples indicated that the area of land in use at that time was insufficient.

7. Leicester (*Surface Irrigation over clayey soil with underdrains*).

The surface soil at Leicester is of a stiff clayey nature, from 6 to 12 inches deep, overlying 2½ to 3 feet of yellow clay, which in its turn rests upon hard boulder clay and the Keuper marl. The drains are about 4 feet deep. The mechanical analysis of the soil indicated that it was really less stiff than the surface soil at Rugby, but the clay subsoil at Leicester is of a more uniform character than the Rugby subsoil. Taking the number of particles in unit weight of the Nottingham ignited soil at 100, the number in the Leicester ignited soil is 269.

The sewage contains about one quarter of its volume of manufacturing refuse of different kinds, and is of moderate strength as regards nitrogenous matter, though it has in it a relatively large proportion of oxidizable substance, this last being no doubt largely due to the trade refuse present. The actual volume treated per acre of irrigable area is as nearly as possible half that of Nottingham, and the aggregate organic matter also about half (*cf.* diagrams 5 and 6, Section II., Sub-section 11), although the suspended solids going on to the land are in larger proportion than this. Treatment over the first field (arable) removes the larger part of the impurities, more especially as regards suspended solids. The final effluents, from treatment over two or three fields (the second and third field being usually rye-grass or pasture), varied considerably in quality and might be described as moderate, chemically speaking; it should, however, be added that they withstood the incubator test very fairly, *i.e.*, that their keeping property was better than some of the figures of analysis would lead one to expect. The sewage is no doubt a difficult one to treat on such a soil, especially as the ground has a strong tendency to crack in dry weather and thus to let unpurified sewage direct into the drains. This last circumstance of course emphasizes the necessity for repeated treatment under such conditions. The results, however, show that with careful management surface irrigation several times over under-drained clay land may be trusted to produce a fair chemical effluent.

8. South Norwood (*Surface Irrigation over fairly stiff soil with very little underdrainage.*)

At South Norwood the surface soil is less stiff and tenacious than that at Leicester, and this is clearly brought out by the mechanical analysis. It is, however, a little shallower than the Leicester surface soil, viz., from 6 to 10 inches deep. The subsoil is London clay. Taking the number of particles in unit weight of the Nottingham ignited surface soil at 100, Leicester gives 269 and South Norwood 177. The presence of ashes was easily discernable in this soil.

The sewage at South Norwood is purely domestic and it is rather weak. The volume per acre of irrigable area is about five-sevenths that at Leicester and about one-third that at Nottingham, but on the other hand, as at Beddington, the whole of the storm water (amounting on occasions to five times the dry weather flow) is treated at South Norwood, which must of course be a great strain on the farm. Excluding storm water, the actual organic matter dealt with per acre is only about half that at Leicester and one

quarter that at Nottingham (diagrams 5 and 6, Section II., Sub-section 11). The effluents varied in appearance, the general effluents evidently containing rather more suspended matter than the other final effluents, which might show only a trace of this. Speaking generally, they were of moderate quality. That the land was getting too much to do at the time of our observations was fully recognised by the local authorities, who have been for some time past extending their bacterial filters with a view to lightening the burden laid upon the soil. But here again, as at Leicester, we have sufficient data to show that a fair chemical effluent can be obtained by surface irrigation over a lightened clayey soil, mostly laid out in rye grass, which is not under-drained.

Short comparison of results at Leicester and South Norwood.

It is difficult to compare the results obtained at Leicester and South Norwood respectively, since the conditions, apart from the question of drainage, are only to some extent analogous. But, taking everything into account, it would appear that on the whole the system followed at Leicester, viz.: surface irrigation several times over clayey soil with under-drains in the clay sub-soil, is capable of purifying more sewage than that in use at South Norwood—surface irrigation over several plots of undrained clayey soil. In other words, there would seem to be sufficient percolation at Leicester, partly no doubt through small fissures, but partly also in the immediate neighbourhood of the drain pipes, to materially influence the result for the better. At the same time the temperature of the final effluents, both at Leicester and South Norwood differed very little from the temperature of the air at the time of drawing, which is a strong argument against much percolation having taken place at Leicester.

Before concluding, one or two points may be touched upon, having reference to some of the remaining sewage farms where only a few observations were made for the Commission, details being given in the separate Farm Reports in Part II.

Mickleover and Hemsworth.

The *Mickleover* and *Hemsworth* farms afford instances of sewage treatment on *very shallow surface soils overlying stiff clay, i.e.*, on types of soil not well adapted for the treatment of sewage. But even under such unfavourable conditions the Mickleover effluents furnish an illustration of the point emphasised elsewhere in this Report, viz., that (the question of) purification by a soil is one of degree rather than one of intrinsic ability or disability.

Worsley.

The *Worsley* farm effluents from that portion of the farm which consisted of pure *peat* land were, as might have been expected, far from satisfactory, though even here there was a very considerable degree of purification. Without at all recommending peat land for the treatment of sewage, it is interesting in this connection to recall a laboratory experiment made by the Rivers Pollution Commission (Vol. I., *First Report*, p. 69), as follows :—

> "These analytical results show that, although the action of the "Lancashire peat upon sewage is for a couple of months but slight and "unsatisfactory, yet the subsequent steady improvement of the effluent "water encourages the hope that this material would, after a somewhat "longer education, become an efficient purifier of sewage filtered "through it at the rate of 49 gallons per cubic yard, per 24 hours."

Luton.

Cities and towns such as Winchester and Luton, whose sewage farms are on the *chalk*, find themselves in the fortunate position of being untroubled by effluents, for the sewage at these places sinks into the ground and disappears. For this reason, attention may be drawn for a moment to the effluents obtained artificially by the filtration of the Luton sewage through different thicknesses of chalk *in situ, with previous removal of the surface soil.* The results of the chemical analyses showed that the sewage underwent comparatively little *direct* purification in its *rapid* passage through 3 feet of chalk. This emphasizes the necessity for the careful examination of all well and spring waters which could by any possibility come within the sphere of influence of a chalk sewage farm.

Dr. Poore's Village System of Sewage Disposal.

Two visits were paid to Andover in connection with the interesting experiments on village sewage disposal which have now been carried out by Dr. Poore for a number of years. The short notes of these visits, with the analytical results, will be found in the Engineering, Bacteriological and Chemical Reports respectively.

Filtration v. Surface Irrigation Effluents.

The foregoing results show how difficult it is to generalize here, or to say dogmatically that one of those classes of effluent is better than the other, seeing that the soils in both types of farms differ so much in quality. To put the matter broadly, one may say that the best effluents are to be obtained by filtration through such soil and subsoil as those at Nottingham, the land being cropped. It is very improbable that any irrigation farm dealing with a reasonable quantity of sewage could produce such effluents. At the same time an irrigation farm on good soil, such of that at Beddington, can also yield very excellent results. The irrigation effluents from heavy soils cannot be expected to reach the highest standard, though even here fair results can be obtained by a proper regulation of the dose of sewage, and effluents either free or practically free from suspended solids produced; whether such effluents would ever be colourless, like the best filtration effluents, is doubtful. The sometimes large quantity of very flocculent (and therefore very light) matter that may be brought down from the drain pipes by filtration effluents is a point that merits attention. Judging from the earlier samples at Nottingham, these flocculent solids need not be present if the land is suitable, and if the volume of sewage treated is moderate in amount.

Influence of season upon the chemical quality of effluents.

So far as our results go, the quality of the various effluents from the different farms did not vary very materially at different times of the year, though in summer and early autumn the effluents were necessarily more concentrated than during the colder months. On the whole they were not quite so good in the warm seasons.

This point should in future be tested systematically by the rate of absorption of dissolved oxygen (*see* below, sub-section dealing with chemical standards of purity for sewage effluents; also section upon Standards in Part II., Chemical Report).

TABLE A.—TABLE OF AVERAGE FIGURES SHOWING THE

NAME OF FARM. Number of Samples of Sewage Examined.	ALTRINCHAM. 4 Chance samples of sewage and 5 of lagoon liquor.	ALDERSHOT CAMP. 9 Chance samples and 3 sets of hourly samples.	CROYDON (BEDDINGTON). * 5 to 7 Chance and 7 sets of hourly samples.
Parts per 100,000 *by weight.*	Average.	Average.	Average.
Total nitrogen :—Chance samples.	2·06 to 5·01=**3·56**	12·45 to 24·89=**17·6**	6·82 to 13·42=**9·50**
Hourly samples.	—	12·31 to 14·24=**13·3**	6·42 to 7·59=**7·18**
Ammoniacal nitrogen : — Chance samples.	0·69 to 3·69=**2·29**	8·26 to 16·94=**12·30**	4·15 to 9·71=**7·34**
Hourly samples.	—	7·60 to 8·21=**7·87**	4·18 to 5·11=**4·50**
Total organic nitrogen : — Chance samples.	0·69 to 3·69=**2·29**	3·39 to 9·10=**5·35**	2·03 to 4·06=**3·37**
Hourly samples.	—	4·25 to 6·18=**5·06**	1·31 to 2·88=**2·07**
Albuminoid nitrogen : — Chance samples.	0·20 to 1·14=**0·62**	2·05 to 3·63=**2·77**	0·99 to 2·36=**1·72**
Hourly samples.	—	1·54 to 1·69=**1·62**	0·59 to 1·12=**0·91**
"Oxygen absorbed" from permanganate at 26·7° C. (80° F.) *in four hours* :—Chance samples.	2·29 to 6·98=**5·22**	20·68 to 38·47=**25·94**	7·91 to 18·73=**13·70**
Hourly samples.	—	19·54 to 22·40=**20·79**	7·85 to 17·45=**12·48**
Chlorine :—Chance samples.	7·22 to 12·88=**9·43**	8·90 (?) to 13·98=**11·38**	5·70 to 10·50=**8·15**
Hourly samples.	—	11·36 to 19·78=**14·98**	7·86 to 9·22=**8·34**
Solids in Suspension (gravimetrically) :—Hourly samples.	—	32·0 to 39·8=**36·6**	21·2 to 53·0=**34·5**
"Cellulose" in Solids in Suspension :—Hourly samples.	—	9·0 to 12·68=**10·79**	—
Parts per 100,000 *by Volume.*			
Solids in Suspension, as determined by Centrifuge :—Chance samples†	27 to 99=**72** 2 sewages and 3 lagoon liquors.	—	—
Hourly samples.†	—	148 to 216=**173**	173 to 356=**218**
*Ratio of Solids in Suspension to Centrifuge solids : — Hourly samples.	—	1 : 3·9 to 1 : 5·4 =**1 : 4·7**	1 : 4·8 to 1 : 8·2 =**1 : 6·6**
Ratio of "Celluloses" to Suspended Solids (grav.) :—Hourly samples.	—	1 : 8·1 to 1 : 11·2 =**1 : 9·7**	1 : 3·6 to 1 : 6·2 =**1 : 4·8**
**Note.*—This is a comparison of a figure expressing weight with one expressing volume.			

* Some of the samples were subjected to more tests than others.
† These figures express the *volumes* of the muds.

Chemical Composition of the different Sewages.

Cambridge.	Leicester.	Nottingham.	Rugby.	South Norwood.
5 Chance samples and 3 sets of hourly samples.	5 Chance samples and 3 sets of hourly samples.	4 Chance and 3 sets of hourly samples.	8 Chance samples and 3 sets of hourly samples.	4 to 7 Chance and 7 sets of hourly samples.
Average.	Average.	Average.	Average.	Average.
1·50 to 11·52=**3·94**	2·90 to 8·61=**5·57**	4·68 to 7·86=**6·39**	2·80 to 14·94=**9·95**	3·52 to 10·84=**7·07**
5·60 to 5·80=**5·71**	7·32 to 9·16=**8·12**	7·53 to 7·82=**7·69**	9·39 to 9·99=**9·65**	4·46 to 5·63=**5·20**
0·89 to 7·31=**2·41**	2·90 to 8·61=**5·57**	3·21 to 5·32=**3·92**	1·95 to 11·21=**7·37**	5·35 to 7·60=**6·50**
3·77 to 3·85=**3·82**	7·32 to 9·16=**8·12**	3·08 to 4·53=**3·98**	5·74 to 6·46=**6·11**	3·15 to 4·05=**3·54**
0·39 to 4·09=**1·29***	1·18 to 2·41=**1·68***	1·47 to 4·24=**2·42***	1·61 to 5·57=**2·54**	2·04 to 3·24=**2·55**
1·73 to 1·95=**1·88**	2·10 to 2·53=**2·34**	2·56 to 4·21=**3·15**	2·87 to 3·55=**3·29**	1·02 to 1·90=**1·49**
0·28 to 1·52=**0·62**	0·66 to 1·70=**1·11**	1·18 to 2·63=**1·77**	0·40 to 2·84=**1·49**	0·98 to 1·23=**1·07**
0·89 to 0·96=**0·91**	0·97 to 1·44=**1·19**	1·17 to 1·99=**1·45**	1·56 to 1·80=**1·73**	0·55 to 1·04=**0·67**
2·07 to 17·81=**6·99**	7·77 to 16·41=**12·45**	10·97 to 25·06=**17·64**	3·55 to 33·31=**15·0**	6·74 to 20·08=**11·40**
9·49 to 10·68=**10·08**	20·28 to 24·83=**22·35**	21·03 to 26·29=**23·12**	17·55 to 19·18=**18·44**	5·43 to 9·77=**7·71**
4·95 to 10·30=**6·37**	3·51 to 11·94=**8·10**	9·66 to 23·42=**16·35**	4·86 to 18·30=**11·68**	7·28 to 8·88=**7·87**
7·90 to 8·74=**8·45**	12·50 to 13·84=**13·38**	11·25 to 15·36=**13·68**	9·36 to 10·46=**9·99**	7·08 to 8·00=**7·45**
23·8 to 28·6=**26·5**	33·6 to 34·8=**34·1**	34·4 to 79·2=**51·9**†	43·0 to 50·6=**47·3**	9·6 to 38·2=**21·9**
3·84 to 5·08=**4·48**	6·56 and 5·80=**6·18**	5·32 to 15·08=**8·88**†	5·88 to 7·92=**7·22**	—
—	—	—	—	—
146 to 176=**160**	160 to 261=**196**	--	258 to 345=**304**	80 to 245=**139**
1 : 5·5 to 1 : 6·5 =**1 : 6·0**	1 : 4·8 to 1 : 7·5 =**1 : 5·8**	—	1 : 6·0 to 1 : 7·1 =**1 : 6·4**	1 : 4·7 to 1 : 9·1 =**1 : 6·6**
1 : 5·6 to 1 : 6·2 =**1 : 5·9**	1 : 5·3 to 1 : 5·8 =**1 : 5·6**	1 : 5·3 to 1 : 6·7 =**1 : 6·2**	1 : 6·1 to 1 : 7·3 =**1 : 6·6**	—
* This figure is possibly too low.	* This figure is possibly too low.	* This figure is probably too low. † These figures are probably higher than the normal.		

TABLE B.—TABLE WITH SOME OF THE AVERAGE FIGURES SHOWING

NAME OF FARM.	ALTRINCHAM.	ALDERSHOT CAMP.	CROYDON (BEDDINGTON.)
Number of samples of effluents examined.*	14 to 16	16 to 18	15 to 16 (Of the final effluents two were over 2 fields only.)
Parts per 100,000 *by weight.*	Average.	Average.	Average.
Total nitrogen - -	1·36 to 4·99=**2·22**	3·69 to 8·99=**6·0**	1·02 to 3·49=**2·20**
Ammoniacal nitrogen - -	0·65 to 1·87=**1·23**	0·91 to 4·98=**1·85**	0·23 to 3·10=**1·48**
Albuminoid nitrogen - -	0·07 to 0·25=**0·13**	0·12 to 0·47=**0·26**	0·06 to 0·23=**0·14**
Total organic nitrogen - - -	0·10 (?) to 0·45=**0·26**	—	0·09 to 0·55=**0·26**
Nitric + nitrous nitrogen - -	0·0 to 3·64=**0·76**	0·0 (?) to 5·97=**3·21**	0·03 to 1·43=**0·37**
"Oxygen absorbed" from permanganate at 26·7°C. (80°F.) *in four hours.*	0·92 to 2·65=**1·75**	1·02 to 5·68=**2·72**	0·90 to 2·09=**1·41**
Incubator test (as judged by smell)-	**81**% passed (16 samples tested.)	**89**% passed (18 samples tested.)	**73**% passed (15 samples tested.)
* Some of the effluents were subjected to more tests than others.			

TABLE C.—TABLE SHOWING APPROXIMATELY THE PERCENTAGE CHEMICAL PURIFICA-ON (a) ALBUMINOID NITROGEN AND (b)

NAME OF FARM.	ALTRINCHAM.	ALDERSHOT CAMP.	CROYDON (BEDDINGTON).
(a) Calculated on Albuminoid nitrogen;	**79**%* On Chance samples of sewages and lagoon liquors together.	**94**% on Chance samples. **84**% on Hourly samples of sewage.	**92**% on Chance samples. **89**% on Hourly samples.
(b) Calculated on "Oxygen absorbed" from permanganate at 26·7°C. (80° F.) *in four hours.*	**67**%*	**90**% on Chance samples. **87**% on Hourly samples of sewage.	**90**% on Chance samples. **89**% on Hourly samples.
	*This calculation is very approximate and of doubtful value.		

THE CHEMICAL COMPOSITION OF THE DIFFERENT FINAL AND GENERAL EFFLUENTS.

CAMBRIDGE.	LEICESTER.	NOTTINGHAM.	RUGBY.	SOUTH NORWOOD.
17 to 18	8 to 13	13	16 to 19	11 effluents (total nitrogen and "oxygen absorbed"); 6 effluents (ammoniacal and albuminoid nitrogen). These include three 2-field effluents.
Average.	Average.	Average.	Average.	Average.
1·48 to 3·19=**2·09**	1·84 to 3·64=**2·53**	1·41 to 3·45=**2·27**	1·39 to 2·96=**2·31**	0·55 to 2·83=**2·30**
0·22 to 1·31=**0·65**	0·59 to 2·81=**1·65**	0·01 to 0·29=**0·13**	0·97 to 2·81=**1·62**	0·02 to 1·55=**0·87**
0·04 to 0·18=**0·09**	0·07 to 0·35=**0·20**	0·01 to 0·10=**0·03**	0·08 to 0·39=**0·18**	0·07 to 0·14=**0·10**
0·04 (?) to 0·42=**0·21**	0·18 to 0·63=**0·45**		--	—
0·69 to 2·25=**1·26**	0·0 to 1·73=**0·51**	1·25 to 3·29=**2·06** and 1·24 to 1·71 in four later samples.	0·0 to 1·59=**0·52**	0·14 to 0·74 (?)=**0·39**
0·16 to 1·31=**0·81**	1·70 to 4·47=**2·50**	0·05 to 0·37=**0·19**	0·72 to 2·16=**1·41**	0·97 to 1·73=**1·44**
94% passed (18 samples tested.)	**92**% passed (13 samples tested.)	**100**% passed (17 samples tested.)	**75**% passed (20 samples tested.)	**75**% passed (12 samples tested.)

TION ON THE VARIOUS SEWAGES EFFECTED AT THE DIFFERENT FARMS, AS CALCULATED "OXYGEN ABSORBED" FROM PERMANGANATE.

CAMBRIDGE.	LEICESTER.	NOTTINGHAM.	RUGBY.	SOUTH NORWOOD.
85% on Chance samples. **90**% on Hourly samples.	**82**% on Chance samples. **85**% on Hourly samples.	**99**% on Chance samples. **98**% on Hourly samples.	**88**% on Chance samples. **89**% on Hourly samples.	**91**% on Chance samples. **85**% on Hourly samples.
88% on Chance samples. **92**% on Hourly samples.	**80**% on Chance samples. **88**% on Hourly samples.	**99**% on Chance samples. **99**% on Hourly samples.	**91**% on Chance samples. **92**% on Hourly samples.	**87**% on Chance samples. **81**% on Hourly samples.

Sewages and Effluents.—Some Average Ratios of Analytical Figures.

It may not be without interest if some of the approximate average ratios of the figures of analysis which have been worked out for the sewages and effluents are given here. At the same time it should be steadily borne in mind that although, *on the average*, the figures for any two determinations (say, determinations of albuminoid nitrogen and "oxygen absorbed") may yield a fairly constant ratio, the ratios in individual samples may yet vary within such wide limits as to preclude any idea of one test being used as a substitute for another. Fuller details of these ratios, giving the extreme figures in the individual cases, are to be found in the Chemical Reports for each of the principal farms in Part II.

(A) Sewages.—Most of the following average ratios for sewages have been obtained from seven different farms.

(1) *Average Ratio of Total Nitrogen to Total Organic Nitrogen* = about 3 : 1.—Extreme averages, 2·5 : 1 and 3·6 : 1.

(2) *Average Ratio of Total Nitrogen to Albuminoid Nitrogen* = about 7 : 1.—Extreme averages, 5·6 : 1 and 8·2 : 1.

(3) *Average Ratio of Total Organic Nitrogen to Albuminoid Nitrogen* = about 2 : 1.—Extreme averages, 1·7 : 1 and 3·1 : 1.

(4) *Average Ratio of "Oxygen absorbed" from permanganate in 4 hours at 26·7° C. (80° F.) to Total Organic Nitrogen.*—In the domestic sewages this varied between about 4 : 1 and 5·6 : 1.

(5) *Average Ratio of "Oxygen absorbed" in 4 hours to Albuminoid Nitrogen.*—In the domestic sewages this was about (10 – 12) : 1.

(6) *Average Ratio of Centrifuge* Solids to Suspended Solids determined gravimetrically.*—Excluding Aldershot Camp, where the solids were heavier, and the average ratio 1 : 4·7, the average figures for Rugby Leicester, Beddington, Cambridge and South Norwood were remarkably constant, only varying between 5·8 : 1 and 6·6 : 1.

(7) *Average Ratio of Suspended Solids to the "Cellulose"† they contained*—Again excluding Aldershot Camp, with a high average, the average ratios in the case of Nottingham, Rugby, Leicester and Cambridge only varied between 5·6 : 1 and 6·6 : 1. That is to say, about one-sixth by weight of the suspended solids in the sewages consisted of "cellulose."

(8) *Relation between Chlorine and Ammoniacal Nitrogen.*—A study of the curves of the sets of hourly sewage samples shows that in the domestic sewages the chlorine curve follows that for ammoniacal nitrogen very evenly, but that there is no relation between it and the "oxygen absorbed" curve. In an average set of hourly samples of a domestic sewage, therefore, the amount of chlorine might be taken as a rough guide to the ammoniacal strength of the sewage, but in chance samples it might not infrequently be misleading.

(B) Final and General Effluents.

(1) *Total Nitrogen.*—If we leave out of account the effluents from the strong sewage at Aldershot Camp, which contained an average of 6·0

* Strictly speaking, it is illogical to contrast a figure expressing volume with one expressing weight.

† Cf. Report on Methods of Chemical Analysis (Part V.).

parts of Total Nitrogen per 100,000, it is rather remarkable that the *average figures* for this in the seven other farms only varied within the comparatively narrow limits of 2·09 and 2·53.

(2) *Ratio of Total Nitrogen to* (*a*) *Total Organic and* (*b*) *Albuminoid Nitrogen.*—There is no necessary relation between the curves for Total Nitrogen on the one hand, and those for Total Organic and Albuminoid Nitrogen on the other, seeing that the degree of oxidation of the different farm effluents varied considerably.

(3) *Average Ratio of Total Organic Nitrogen to Albuminoid Nitrogen.*—In the case of Cambridge, Altrincham, Beddington and Leicester, the *average* Albuminoid Nitrogen in the effluents constituted almost exactly half of the average Total Organic Nitrogen, *i.e.*, the above ratio was 2 : 1. In the case of the other farms the data are insufficient.

(4) *Average Ratio of "Oxygen absorbed" from permanganate in* 4 *hours at* 26·7° *C.* (80° *F.*) *to Albuminoid Nitrogen*—If there had been anything like a constant ratio here, it would have been of special interest, because of those two tests being so frequently relied upon for determining the quality of an effluent. But although the *average* ratio for the eight farms works out to about 11 : 1, and the extreme averages 7 : 1 and 14 : 1, the individual ratios in the case of Nottingham, Altrincham, Aldershot Camp and Leicester are very uneven; in the case of South Norwood, Cambridge, Rugby and Beddington they are fairly even within rather wide limits. In no instance, however, could the one test have been taken as a substitute for the other. Speaking generally, the better effluents have the lower ratios, though this is not by any means always the case. (*Cf. Part II.*, *Conclusions* to Chemical Report).

(5) "*Safety*" *Ratio of Oxidised to Albuminoid Nitrogen.*—By this is meant the minimum ratio of (nitric + nitrous) nitrogen to albuminoid nitrogen in an effluent which will prevent that effluent from becoming putrescent upon incubation. In the case of one or two of the Cambridge effluents, this ratio appeared to be a rather high one, while in the effluents from Aldershot Camp, Altrincham, Beddington, Rugby and Leicester, it varied between 4 : 1 and 1·5 : 1. Probably a ratio of 3 : 1 or 4 : 1 would be sufficient to cover all fairly purified land effluents.

Smell of Effluents.—Attention should be paid to the smell of an effluent when it is drawn, for it may in certain cases smell of sewage and yet contain a sufficient reserve of nitrate to keep it sweet upon incubation. Still such an effluent would take up dissolved oxygen from surrounding water somewhat rapidly, and hence it cannot be considered as properly purified.

Brook and River Waters.

In the *General Bacteriological Conclusions* (Section VI.), arguments have been brought forward to show that no brook or river into which an effluent from a sewage farm flows should be used as a source for drinking water. *In what follows, therefore, the streams are regarded from the point of view of non-drinking waters.*

Fifty-four samples in all of brook or river water from the various farms, drawn either above the effluent outfall or below it, were examined, some of them in duplicate after being kept for a time: this is, of course, not a large number from which to deduce general conclusions, and any remarks made with regard to the brooks or rivers must therefore be read subject to this proviso. The details of the analyses are to be found in the separate Farm Reports of Part II., and the results are summarized a little more fully than here in the *Conclusions* to the Chemical Report.

1. *Aldershot Camp Farm; River Blackwater.* Normal ratio of farm effluent to river water, 1 : 6.

This small river was not in a satisfactory state at the times when our observations were made, more especially during summer, but this was due to polluting matter entering it above the farm. The Aldershot Camp Farm effluent from the old land must have exercised an oxidising effect on the organic matter already present in the water. At the same time attention should again be called to the rather considerable bulk of fine flocculent weed (from the drain pipes) which is carried into the stream along with the effluent and also to the high manurial value of the effluent itself. Not only is there a great loss of nitrate and other manurial constituents here, but the effluent must tend to choke the stream indirectly by encouraging vegetable growth in it.

2. *Altrincham Farm; Sinderland Brook.* Normal ratio of effluent to brook water, 1 : 3.

Like the Blackwater, the Sinderland Brook was polluted before it reached the Altrincham Farm (speaking generally, the farm effluent must have had an oxidizing effect upon it), and was not in a satisfactory state at the time when our observations were made.

3. *Cambridge; River Cam.* Normal ratio of effluent to river water, 1 : 15.

At Cambridge the river was in a fair condition in January and February, 1901. Of course the comparatively large volume of river water here minimises any effect that the effluent may exert upon it.

4. *Croydon (Beddington); River Wandle.* Normal ratio of effluent to river water, 1 : 8; ratio at first time of sampling, 1 : 12.

Judged by a non-drinking water standard, little or no fault was, on the whole, to be found with the water of the River Wandle in February and October, 1900, though the samples examined were not altogether free from flocculent matter. Here, again, we have a comparatively large volume of river water as compared with that of effluent.

5. *Leicester; the Anstey Brook.* Ratio of effluent to brook water at time of sampling 1 : 1.

The volume of water in this small brook is sometimes less than that of the combined effluents from the farm in summer, but the flow is fairly rapid; in the Engineering Report reference is made to the green growths in the stream. The samples tested varied somewhat, as was to be expected with such a small flow of water, and they contained appreciable amounts of suspended solids, no doubt from the effluent drain pipes; but, taking the existing circumstances of small dilution into account, the condition of the brook might be regarded as fairly satisfactory from a chemical point of view.

6. *Nottingham; the Trent.* Ratio of farm effluent to river water, say 1 : 160 ; the variations in volume are great, but the minimum ratio is about 1 : 60.

In the months of July and August, 1900, the water of the Trent was not at all of high quality, though there was nothing offensive about it; it contained for a river water a large proportion of oxidizable matter, and usually a considerable quantity of solids in suspension. The volume of effluent as compared with that of the river water is very small, but, so far as it goes, the effluent must exercise an oxidizing effect on the water of the river, which—as stated in the Engineering Report—receives the sewage from most of the populous villages on its banks.

7. *Rugby: the Avon.* Normal ratio of farm effluent to river water, 1 : 20 ; ratio at second time of sampling, 1 : 30.

The water of this river was, on the whole, in fair condition chemically, at the time of our observations, but in summer the large amount of oxidizable matter in one of the samples drawn above the effluent outfall showed that there was at the time some polluting liquid—not from the high level farm—entering the river. The volume of river water to effluent is again rather large here.

8. *South Norwood; the Chaffinch Beck.* Ratio of effluent to brook water at second time of sampling, 3 : 1.

Even in winter the volume of this little stream often does not exceed that of the farm effluent, while the Engineering Report states that in dry seasons very little effluent leaves the farm at all, owing to evaporation. It is further noted in that report that the beck evidently receives a certain amount of pollution from surface water drains which join the effluent ditch before the effluent itself flows into the brook. The samples of water examined contained very appreciable amounts of brownish flocculent matter in suspension and showed too much oxidizable matter generally. There was no question of nuisance arising, and three out of the four samples were well aerated when analysed, but the relatively high figures for "oxygen absorbed" from permanganate showed that, from one cause or another, this little brook—judged from a brook-water standard—was not in a very satisfactory condition at the time our few observations were made.

9. *Worsley; the Parrin Brook.*

This brook, which is of small volume, was in a very unsatisfactory state when our samples were drawn and examined. It is however noted in the Engineering Report that the contamination of the water arose not merely from the effluent of the Worsley Farm, but also from that of another sewage farm higher up the stream.

Conclusion.

It will thus be seen that the rivers or brooks at about half of the farms were not in a satisfactory condition, but that in nearly every one of those cases the material pollution took place *above* the farm effluent outfalls, *i.e.*, the streams were polluted before they arrived at the farms. Leaving out the contingency of having a sewage farm on peat or other wholly unsuitable land, *assuming always that the water is not to be used for drinking or domestic purposes*, and speaking in general terms, there seems no reason why the purity of a brook or river should be so affected by the discharge of an effluent from a well-managed sewage farm as either to give rise to any nuisance, or, so far as can be judged in the present state of our knowledge, to injure fish life.

Subsoil Waters.

Fifteen samples of subsoil, well and spring waters, drawn from unsewaged land, either on some of the sewage farms or close to them, were examined, a few of these samples being from the same sources but drawn at different times. The details of the analyses are given in the separate Farm Reports and Tables of Part II., and they are summarized pretty fully in the *Conclusions* to the Chemical Report. A few words may, however, be devoted to them here :—

The samples drawn at the Leicester and Cambridge farms were pure organically; the Aldershot Camp well-water contained a very considerable amount of organic matter, apparently of vegetable origin; the Rugby well-water, drawn from a well situated within 40 feet of sewaged land, showed that while from its composition the water was in all probability derived from the sewage of the farm, it had undergone in its passage through the soil a most efficient filtration and purification, chemically speaking; the Altrincham subsoil water could only be classed as a moderately good effluent; the Luton well-water showed evidence of pollution, but this was probably due to fæcal matter dug in as manure close to the well; the Luton spring water was good chemically, though there are one or two points about it which require further investigation; lastly, two of the three samples of water drawn from the unsewaged peat land on the Worsley Farm were evidently free from sewage contamination (they showed the usual characteristics of peaty water).

With so few samples, taken under such diverse conditions, it would be unwise to attempt any generalization other than that the results show that very great care is necessary with respect to drinking water supplies drawn anywhere in the neighbourhood of sewage farms.

Storm-Waters.

Only one sample of storm-water from a farm was examined, viz., No. 68, drawn at Altrincham after the overflow had been working for an hour and a-half. This was a dilute sewage, and putrid when received, though containing only a small quantity of black deposit.

During the past year, however, we have been enabled by the courtesy of Mr. Tatton, of the Mersey and Irwell Joint Committee, to examine about thirty samples of storm-water from Macclesfield, Rochdale and Stockport. So far, nearly all of these have been drawn on the ascending curve of the storm, the dilutions ranging between three and seven times the dry weather flow,—in the majority of cases three to four times. In quality those storm-waters might be classed as varying between exceptionally strong and very weak sewages, nearly half of them being weak, and the remainder medium to strong. A few of them contained extraordinary amounts of suspended solids (up to 366 parts per 100,000), others only small quantities. When the samples came to be analysed, about two-thirds of them were more or less inoffensive as regards smell, the remaining third having a sewage odour. Fully half of them were subjected to the incubator test, with the result that they became putrid; and, no doubt all the others would have done the same. In comparing sets of samples drawn on the same day, at intervals during the storm, it was seen that the liquid might continue to be bad during a flow of two or three hours; this is, of course, a point of great importance.

The investigation is proceeding, but the results already obtained are sufficient to emphasize the necessity for settling and treating storm-waters up to the limit of dilution that a sewerage system may reasonably be asked to provide for (*cf.* Section IX.—General Conclusions).

Surface Street Washings.

Seven samples were examined, viz., Nos. 174, 179, 182 and 187A, from South Norwood; No. 231, from Rugby; and Nos. 311 and 314, from Aldershot Camp. The detailed analyses of these are given in the Tables

appended to the respective Farm Reports (Part II.), and the results are summarized in the *Conclusions* of the Chemical Report. Three of the samples contained so little organic matter that they withstood the incubator test, but the others did not; of those four others, two might be classed as dilute sewages, the remaining two being weaker. Although the above samples were few in number, they show at all events;—

1. That even when a street water is comparatively pure organically, it requires settlement for grit (Nos. 174 and 231).

2. That even after long-continued rain, street surface waters may be very impure (Nos. 182, 311 and 314).

Chemical Standards of Purity for Sewage Effluents.

The question of what considerations should weigh most in recommending a working chemical standard of purity for sewage effluents is a very difficult one.

The standard of purity for effluents recommended by the Rivers Pollution Commission for 1868 has already been given (Section III.). So far as regards matter in suspension and organic matter in solution it is :—

(a) The liquid shall not contain, as solids *in suspension*, more than 3 parts by weight of dry mineral matter, or more than 1 part by weight of dry organic matter in 100,000 parts of effluent.

(b) It shall not contain *in solution* more than 2 parts by weight of organic carbon or more than ·3 part by weight of organic nitrogen per 100,000.*

The Mersey and Irwell River Board *provisional* standard (converted into terms of nitrogen and into parts per 100,000) is :—

·12 part albuminoid nitrogen per 100,000*, and 1·43 parts "oxygen absorbed" from permanganate in 4 hours at 60° F. (15·6° C.). At the same time this Board also takes into account the rate at which an effluent takes up dissolved oxygen and nitrate from water.

Dr. Barwise, of the Derbyshire County Council, recommends the following :—

		Parts per 100,000.
Total suspended matter - - - - -	less than	3·0
"Oxygen absorbed" at 80° F. in 4 hours - - - - -		1·5
Albuminoid ammonia - - - - - - - -		0·15
(Equal to albuminoid nitrogen 0·12)		
Nitrogen as nitrates - - - - - - -	at least	0·25

This last approximates to the Mersey and Irwell standard (excepting that the "oxygen absorbed" test is done at 80° F. instead of 60° F.), but with the addition of a small quantity of nitrate as a safeguarding factor.

Mr. Dibdin has always accepted the standards laid down by the Mersey and Irwell Joint Committee, which he considers very fair working standards. (He determines "oxygen absorbed," however, at a temperature of 80° F. instead of 60° F. and uses a strong permanganate solution). But, in addition, he feels very strongly that the maintenance of the dissolved oxygen, on keeping, at a point above 50 per cent. of the total possible, is one of the most important considerations, as it shows the capability of the effluent to support fish life.

Dr. Rideal judges the quality of an effluent to a large extent from the ratio of oxidized to unoxidized nitrogen in it. At the same time he takes into account the ratio of chlorine to total nitrogen, as giving a good approximation to the original amount of animal matter present in the crude sewage.

Dr. Adeney is opposed to any hard-and-fast standard, being of opinion that standards should vary according to local circumstances, as otherwise small and poor communities might be very hardly dealt with. (Report of the present Sewage Commission, 1898, Vol. II., Ques. 2421–2426.)

The West Riding Rivers Board has not published any standard, but we understand from Dr. Wilson that it relies mainly upon the "oxygen absorbed" test at 80° F., and at the same time allows for the presence of nitrate in an effluent.

The Thames Conservancy has likewise not published any standard.

The Ribble Joint Committee has not officially fixed upon any standard, but uses *provisionally* the following figures as a rough working classification :—

Albuminoid ammonia,	if under 0·1 part per 100,000	- Effluent good.
,, ,,	0·15 to 0·2 - - - - -	- Unsatisfactory.
,, ,,	over 0·2 - - - - - -	Bad.

Without quoting further opinions, it is thus evident that the views upon standards held by acknowledged authorities on the subject of sewage purification differ considerably from one another.

* *Note.*—It will be seen that, as regards organic nitrogen, these two standards are pretty much the same. In the final effluents examined for the Commission from the Cambridge, Altrincham, Beddington and Leicester farms, the albuminoid nitrogen constitued *on the average* almost exactly one-half of the total organic nitrogen (the data for this ratio in the case of the other farms are insufficient).

We do not propose at present to touch upon the question whether or not the chemical standard of purity for an effluent might be allowed to vary within certain limits, according to the volume of the stream into which the effluent flows, but merely to consider upon what principles a standard might reasonably be based, supposing the Commission were ultimately inclined to recommend one.

A standard may be either (1) one of the non-putrescibility of an effluent, without any regard to the rate at which that effluent takes up oxygen; or it may be (2) one of non-putrescibility, having regard also to the rate at which oxygen is taken up. It is of course obvious that the second must be the higher standard of the two. In both cases it is assumed that suspended solids are either absent or at all events are not present in larger quantity than allowed for by the Rivers Pollution Commission.

(1) An effluent may show itself to be non-putrescent under the incubator test, and may be either a good or an indifferent effluent (though the probabilities are in favour of its being good), that is to say, it may be a sample which is already so fully oxidised as not readily to take up oxygen from the water of a stream; or, on the other hand, it may be only partially oxidised, and therefore prone to take up oxygen from surrounding water, but at the same time be kept from being offensively putrescent by the presence of excess of nitrate* (*cf.* Section upon "Artificial Storm Waters" in the Chemical Report). While the incubator or non-putrescibility test is therefore a most valuable one when taken in conjunction with others, it cannot be recommended alone as a basis for a standard. It is not impossible, also, that an effluent only partially purified, but still containing sufficient nitrate to enable it to withstand the incubator test, might tend to deposit colloidal matter which—separated from the nitrate in solution—might be putrescible. Another and not unimportant point to bear in mind is that the incubator test requires several days for completion; and, moreover, the time limit and the temperature used for this test are quite arbitrary.

(2) Suppose we take the hypothetical case of two sewages *of the same nature*, containing in equal volumes amounts of organic matter expressed by the figures 10 and 5 respectively, then 50 volumes of the first (A) will contain as much organic matter as 100 volumes of the second (B). Hence, if they are both to be purified down to the same *absolute* standard, it is clear that—volume for volume—twice as much purification will require to be done upon A as upon B. Again, the two effluents $(A)_1$ and $(B)_1$, although they give identical percentage figures for, say, albuminoid nitrogen, are not really equally pure, the effluent from the stronger sewage (A) being as a matter of fact better than the effluent from the weaker one (B); for we think it is a point of universal experience that the more the organic matter of an effluent is reduced, the less rapidly fermentable does that residual organic matter become, or, to put this last statement numerically, if two effluents from the same sewage yield albuminoid nitrogen in the proportions of 0·2 and 0·1 parts per 100,000, the first effluent will be *more than twice* as fermentable as the second, *i.e.*, it will have *more than twice* the tendency to take up oxygen.† Any more or less "absolute" standard like the *provisional* one of the Mersey and Irwell Board, therefore, must necessarily press more hardly upon places which have to deal with strong sewages than upon those which treat weak ones.

* *Note.*—There appears to exist doubt in some minds as to whether an effluent, when left to itself, exhausts its dissolved oxygen before beginning to use up its nitrate, or whether both are utilized simultaneously. But we think that the various results bearing upon this point which we have obtained (and which are to be found in the various Chemical Tables of Analyses) are in accordance with the earlier observations of Adeney ("Recent Advances in the Bacterio-Chemical Study of Sewage and other Polluted Waters"; *Engineering*, 1896), which were based on the work of Munro (*Journ. Chem. Soc.*, Vol. 49, p, 651,) and of Gayon and Dupetit (*Station Agronomique de Bordeaux*, 1886, or *Journ. Chem. Soc.*, Vol. 50, Abs. p. 823), and strengthen the conclusion that, in accordance with chemical theory, the oxygen is consumed before the nitrate is touched, provided that the liquid is free from suspended organic matter. Should the latter be present, the upper layers of liquid might still conceivably contain some free oxygen, while the nitrate in solution in the lower layers was being attacked by adjacent organic matter in suspension.

† *Note.*—The experiments upon "Artificial Storm Waters" (See Part II., Chemical Report) furnish an extreme case of this. They show that dilution of a sewage with tap water down to the Mersey and Irwell effluent standard gives a mixture which putresces upon incubation. Even when the dilution is carried twice as far, *i.e.*, down to half the Mersey and Irwell standard, the mixture will still in all probability be putrescible under those conditions.

It might be argued, in reply to the last sentence, that the area of irrigable land on a sewage farm should be proportionate not merely to the volume but also to the organic strength of the sewage which it has to treat (a subject which we have ourselves discussed; *cf.* Section I.; Sub-section XI.); but this only partially meets the point, and, in its turn, it raises the question—whether is it easier to purify 50 volumes of a stronger sewage (A) or 100 volumes of a weaker sewage (B) on a given area, the *aggregate* organic matter in both sewages being equal? But with respect to this last query we have no comparative data for an answer.

To return to the hypothetical sewages (A) and (B), containing respectively 10 and 5 parts of organic matter:—If these are purified to the same *proportionate* extent, then the effluents $(A)_1$ and $(B)_1$ will contain, say, ·2 and ·1 parts of albuminoid nitrogen per 100,000, *i.e.*, they will be altogether different if judged by an "absolute" standard, but, as regards the rate at which they will take up dissolved oxygen, they will probably approximate to one another.

It seems, therefore, reasonable to suggest that, if any chemical standard of purity is to be ultimately proposed by the Commission, it should be one depending, at all events partially, upon the rate at which oxygen is taken up, all the more since the diminution of the dissolved oxygen in brook and river waters by effluents is one of the main things which we have actually to guard against. This basis is a scientific one and, further, it is one which follows on the lines of some of the most valuable work that has been done upon sewage, *e.g.*, that of the late Sir E. Frankland,* of Dr. Dupré* and of Dr. W. E. Adeney* and others. The principle, too, has for a good while past been practically recognised by men like Messrs. Scudder, Dibdin and Fowler, who carry out "aeration" tests upon this line. For a recent paper on the subject, see also Dr. Rideal, *The Analyst*, Vol. 26. p. 197.

The main objection to a standard depending, in part at least, on the rate of absorption of dissolved oxygen, is that we cannot imitate in the laboratory the ever-changing conditions of a natural stream, and that therefore any dissolved oxygen absorption test that might be recommended for adoption must be an arbitrary one. The whole subject, however, is one with regard to which it would be advisable to collect the views of those workers who have given special attention to the point. There are no doubt already a considerable number of existing records showing the rate of absorption of dissolved oxygen, under definite conditions, by effluents of known chemical composition (in the Mersey and Irwell Laboratory, for example, Mr. Scudder has had the "dilution" method of this aeration test in use for a long time); and further records of the kind are being made now for the Commission.

One of the chief difficulties in connection with this is, should the rate of absorption of dissolved oxygen be tested at an uniform temperature all the year round, say, at about 18° C. or 65° F. (which would practically cover the summer temperature of effluents; *cf.*, Section IV.), or should it be determined at the atmospheric temperature of the day? There is a good deal to be argued in favour of either alternative, *e.g.*:—

---

* NOTE.—In the *First Report of the Rivers Pollution Commission, Vol. I., p.* 20, the following passage occurs:—

"The oxidation of the organic matter in water is effected chiefly, if not exclusively, by the "atmospheric oxygen dissolved in the water; such dissolved oxygen being well known to be, "chemically, much more active than the gaseous oxygen of the air. If, therefore, water "contaminated with organic matter be perfectly excluded from the air in a carefully-stoppered "bottle, the gradual diminution in the amount of dissolved oxygen indicates exactly the progress "in the oxidation of the organic matter."

In the *Supplement to the Report of the Local Government Board for* 1884–5 there is a paper by Dr. Dupré on "*Changes in Aeration of Water, as indicating the nature of the impurities present in it,*" in which he shows, among other things, that the amount of dissolved oxygen taken up by natural waters, in which bacteria are active, is very much greater than the amount of oxygen which the same waters take up from a solution of permanganate. In other words, one cannot necessarily infer, from the rate of absorption of oxygen from permanganate by an effluent, what the rate of absorption of dissolved oxygen from brook water by the same effluent would be.

Lastly, in the *Transactions of the Royal Dublin Society V.* (*Series II.*), 1895, Dr. Adeney writes:—

"I therefore propose, in this communication, to deal with such experiments as bear directly "on the question with which I started this investigation, viz., *whether the amount of dissolved* "*oxygen consumed during the complete fermentation of a polluted water might not be regarded, for the* "*purpose of water analysis, as a quantitative index to the amount of fermentable substances originally* "*present in it, provided that during the process care is taken to have the oxygen in excess in the water.*"

(1) *Test made at uniform temperature.*

(*a*) The standard would in this case remain nearly, though not quite actually, the same throughout the year, taking no account of the temperature at which an effluent was purified (*e.g.*, over land), of its state of dilution or concentration as varying with that temperature, or of the temperature of the stream into which it was discharged; in other words, to put the matter broadly, the comparatively dilute effluent obtained from an irrigation farm in cold frosty weather would be judged by the same standard as the comparatively concentrated effluent got from the same farm in warm weather.

(*b*) On the other hand, the test would not be quite so easy to carry out and, unless there was a laboratory at the sewage farm or works, it could not be applied to an effluent until the latter had reached the laboratory where it was to be tested, which, as a rule, would be on the succeeding morning. Since the bacteria which are active with regard to the absorption of dissolved oxygen are probably most active within the first 24 hours after the effluent is discharged, this delay might be considered a drawback.

(2) *Test made at the atmospheric or laboratory temperature of the day.*

(*a*) In this case the stringency of the standard would vary with the season of the year, being, of course, greater in warm weather; some people might consider this a recommendation, seeing that nuisance from a bad smell arises much more easily in summer than in winter.

(*b*) But the test would be simpler of execution than in the case of (1), and it could, moreover, be put in force the moment a sample was drawn. Thus, a small sample might be aerated by thorough shaking in a large, nearly empty bottle, and the residual oxygen determined 24 hours later, either at the farm or sewage works, or at the laboratory to which the sample was despatched. Or, if more convenient, the dissolved oxygen might be added, as Mr. Scudder does it, *i.e.*, in the form of tap water, though this would rather lengthen the time required for the test.

Without making any definite or final statement on the subject at present, we think it would probably be found that any effluent which did not within the 24 hours after drawing take up more than about 3 to 4 c.c. of oxygen per litre (when kept in a full bottle at, say, 18° C. or 65° F.), would be found to be chemically satisfactory. The test might have to be taken in conjunction with the permanganate "oxygen absorbed" test, to provide against the (unlikely) contingency of an effluent being a sterilized one; and in the present state of our knowledge, it might also be advisable to safeguard it further as regards a maximum of nitrogenous organic matter to be allowed in any effluent at any time (measured, say, by the albuminoid nitrogen), though this additional precaution might in the end be found unnecessary.

We think there can be no doubt that, if it could be satisfactorily and easily worked out in practice, a standard based upon the above principles would deal equably between effluents from strong and weak sewages, not favouring the one at the expense of the other.

SECTION VI.

Summary of the Bacteriological Results and Conclusions.

1. *Can the treatment of sewage on land so modify the biological qualities of sewage as safely to admit of the discharge of the effluents into drinking water streams ?*

Excluding Nottingham, the effluents usually contained 100 to 1,000 B. coli or coli-like microbes and 1 to 10 spores of B. enteritidis sporogenes per c.c. Dilution of such effluents ten or one hundred times even with *sterile* water would leave the mixed liquid potentially dangerous to health. As a matter of fact, however, the river water above the respective effluent outfalls was always so impure *per se* as to be quite unfit for domestic use. It is admitted that (1) extreme dilution of a sewage effluent with a pure river water, (2) long distance of flow of the river between the effluent outfall and the intake of the nearest waterworks company, and (3) subsequent efficient sand filtration at the waterworks, are all modifying factors which, taken singly, much more in conjunction, confer a relative, it may be even a reasonable, degree of safety. But it were wise to judge effluents about to be discharged into drinking water streams on their merits, and unfettered by attention to necessarily variable factors of which the influence cannot readily be weighed or measured. This being so, the conclusion seems to be that, with the apparent rather than real exception of Nottingham* the effluents from land processes of sewage treatment are not in a fit state to be discharged into drinking water streams.

2. *What are the biological qualities of the soil on sewage farms ?*†

The soils of sewage farms and, in general, sewage-polluted soils contain streptococci, B. coli and B. enteritidis sporogenes in great abundance. These objectionable microbes are absent, or *relatively* absent from virgin soils. In cultivated soils, much naturally depends on the nature of the treatment or the kind of "dressing" which has been applied to the soil and the time which has elapsed since the soil was last "treated." The spores of B. enteritidis sporogenes tend to remain for a long period as evidence of past pollution, but B. coli and more particularly streptococci (some strains, at all events), when present in any number, point to contamination of *recent* and therefore specially objectionable kind.

According to whether the manuring is recent or remote, the nature of the fertilising "treatment" and the amount of dressing applied to the soil, the bacteriological results will be found to vary. But cultivated soils, in comparison with virgin soils at all events, are apt to be rich in microbes of all sorts, and rich also not infrequently in bacteria of excremental origin.

But it must not be imagined that because microbes indubitably of intestinal outcome are present in great abundance in sewage-polluted soils, the bacteria characteristic of soil are necessarily in the struggle for existence crowded out by the sewage bacteria. Experience has shown that the soil microbes persist, and, if the supply of sewage microbes be discontinued, contend with and gradually oust such of the non-sporing bacteria of excremental origin as may be judged to be of adventitious sort.

---

* The case of Nottingham is fully dealt with in Part III. (Bacteriological Report).

† In dealing with the subjects under the headings 2, 3, and 4, reports to the Local Government Board by one of us have been largely drawn upon.

3. *What is the ultimate fate of sewage microbes sown broadcast on soil?*

So complex a problem as the above cannot be readily solved, but it would seem to be the case that, given a cessation of application of sewage, the streptococci (other than those of peculiar sort) disappear (*relatively* if not actually) from the soil somewhat rapidly. Decline also in the number of B. coli is very apparent, although the persistence of certain strains of B. coli for weeks or even months is also indicated as the result of actual experiments. Many of these coli-like microbes are apt to give a feebly positive or even negative response to tests, which brought to bear on the coli of recent intestinal outcome provoke a strongly positive result. The problem to be solved depends on whether these coli-like microbes constitute a race or class of their own, or are alvine micro-organisms which have lost some of their original attributes during their sojourn in the soil.

The spores of B. enteritidis sporogenes usually persist for long periods. Such diminution in their number, as has been observed, may be due perhaps to the spores being washed into the deeper layers of soil, or to the gradual dissolution even of spores, or possibly to the spores passing into the vegetative phase of existence, and thus becoming more susceptible to the action of deleterious bactericidal influences of one and another sort. Dr. Lorrain Smith favours the view that the infusoria may utilise the bacteria as food.

4. *Are the effluents from sewage farms rich in microbes peculiar to (in the sense of being specially abundant in) soil, or do they contain in preponderating number microbes of excremental origin?*

As regards the last question, in various reports to the Local Government Board it has been shown by one of us that soil and the "washings" of soil are apt to be characterised bacteriologically by the presence of enormous numbers (both actually and relatively) of the spores of bacteria and by the presence, usually in great abundance, among other soil bacteria of B. mycoides, of the *granular bacillus* of soil, and of the *Bismarck brown cladothrix* of soil. A careful and prolonged comparison of these previously-ascertained results with the results of the examination of the effluents from the sewage farms affords convincing evidence that the effluents from land processes of sewage treatment are not only *characteristic of the bacterial flora of sewage, but are relatively free from soil microbes.*

Occasionally, B. mycoides was met with in the cultivations from effluents, but so rarely as to be hardly worthy of mention. At the same time, it is to be noted that the term "relatively free" not "actually free" has been used, because it might well be the case that in the high dilutions used and necessary for working purposes the soil microbes might be absent and yet be present sometimes in the lower dilutions.

5. *Can the treatment of sewage on land so alter the qualities of sewage as to admit of the discharge of the effluents into non-drinking water streams?*

In the first place, it is to be noted that, of the eight sewage farms kept under special observation, none, with the sole and striking exception of Nottingham, yielded effluents of an entirely satisfactory character.*

In illustration of this, it may be pointed out that the average number of bacteria (agar at 37°C.) per c.c. in the final effluents derived from Aldershot Camp, Altrincham, Cambridge, Beddington, Leicester, South Norwood and Rugby sewage farms was 37,308, 7,275, 78,327, 112,240, 70,500, 35,157, and 81,526 respectively.

Nevertheless, the results were, in nearly all cases and in relation to all the tests employed, so far satisfactory as to give rise to the belief that land, although of not altogether suitable sort, can, if it is not greatly overworked, purify sewage to a reasonable extent.

Secondly, although percentages are apt to be misleading, it may be stated that the percentage improvement in the effluents, as compared with the crude sewage, was in nearly all cases very striking.

---

* The Altrincham effluents, however, were in many respects very good.

Thus, as regards Aldershot Camp, Altrincham, Cambridge, Beddington, Leicester, South Norwood, and Rugby sewage farms, the percentage improvement, as judged by the reduction in the number of bacteria (agar at 37° C.), was 99, 99, 95, 97, 95, 99 and 97 respectively.

Thirdly, it may be pointed out that a significant feature of the analyses was the unequal character of the effluents. In considering the subject from the point of view of possible danger to health and in relation to the discharge of effluents into drinking water streams, stress should perhaps be laid on the grossly impure character of a proportion of the effluents. In the present connection (non-drinking water streams), attention must be directed to the fact that many of the effluents were not only satisfactory but, considering their origin, remarkably pure. Thus, the number of microbes (agar at 37°C.) per c.c. in the best (on the basis of this test) effluent derived from Aldershot Camp, Altrincham, Cambridge, Beddington, Leicester, South Norwood and Rugby sewage farms was 196, 930, 1,080, 900, 300, 980, and 900 respectively.

Lastly, a brief summary of the chief results obtained from the bacteriological examination of the effluents derived from the above seven sewage farms may here with advantage be inserted (*see* next page).

Sewage Farm Effluents.	Average number of bacteria (gelatine at 20° C.)	Average number of bacteria (agar at 37° C.)	Average number of B. coli (or gas-forming coli-like microbes) per c.c. (Approximate.)	Average number of spores of B. enteritidis sporogenes per c.c. (Approximate.)	"Gas" test ("gas" in gelatine "shake" cultures in 24 hours at 20°C.) Average result. (Approximate.)	Neutral red broth test Average result. (Approximate.)	Method of treatment.	Nature of soil and subsoil.	Gallons of Sewage treated per acre per 24 hours.	Gallons of Sewage treated per acre per 24 hours on the assumption that each acre of the irrigable area is under Sewage all the time.
I. Aldershot Camp - - [Purely domestic sewage.]	183,266 (99 per cent. reduction)	37,308 (99 per cent. reduction)	At least 1,000, but less than 10,000.	At least 10, but less than 100.	+ 1 c.c. − ·1 c.c.	+ ·001 c.c. − ·0001 c.c.	Screening, settling tanks and land filtration.	Sand.	25,000	8,300
II. Altrincham - - - [Domestic sewage.]	363,400 (97 per cent. reduction)	7,275 (99 per cent. reduction)	At least 100, but less than 1,000.	At least 1, but less than 10.	+ 1 c.c. − ·1 c.c.	+ ·01 c.c. − ·001 c.c.	Settling tank and land filtration.	Peaty soil lying upon sand and gravel.	46,000	23,000
III. Cambridge - - - [Mainly domestic sewage.]	711,476 (94 per cent. reduction)	78,327 (94 per cent. reduction)	At least 1,000, but less than 10,000.	At least 10, but less than 100.	+ ·1 c.c. − ·01 c.c.	—	Screening, settling tank and land filtration	Sandy loam overlying gravel and sand.	121,600	30,400
IV. Beddington (Croydon) - [Almost purely domestic sewage.]	1,413,200 (95 per cent. reduction)	112,000 (97 per cent. reduction)	At least 1,000, but less than 10,000.	At least 10, but less than 100.	+ ·1 c.c. − ·01 c.c.	+ ·001 c.c. − ·0001 c.c.	Screening, combined surface irrigation and land filtration.	Gravelly loam over gravel and sand.	57,100	9,500
V. Leicester - - - - [Mixed sewage.]	532,777 (95 per cent. reduction)	70,500 (95 per cent. reduction)	At least 1,000, but less than 10,000.	At least 10, but less than 100.	+ ·1 c.c. − ·01 c.c.	+ ·001 c.c. − ·0001 c.c.	Screening, settling tanks, combined surface irrigation and filtration.	Clayey soil overlying dense clay.	21,500	5,370
VI. South Norwood - - [Purely domestic.]	778,322 (98 per cent. reduction)	35,157 (99 per cent. reduction)	At least 100, but less than 1,000.	At least 10, but less than 100.	+ ·1 c.c. − ·01 c.c.	—	Screening, settling tanks, combined surface irrigation and filtration.	Clayey soil resting on London clay.	12,000	4,000
VII. Nottingham - - - [Mixed sewage.]	With a few exceptions (chiefly from purposely overworked land) the effluents were remarkably good, and easily "passed" the standards set up for the above tests.				—	—	Screening (partial) and land filtration.	Sandy loam overlying gravel and sand.	23,300	10,750
VIII. Rugby - - - - [Mainly domestic.]	637,133 (97 per cent. reduction)	81,526 (97 per cent. reduction)	At least 1,000, but less than 10,000.	At least 10, but less than 100.	+ ·1 c.c. − ·01 c.c.	+ ·01 c.c. − ·001 c.c.	Combined surface irrigation and filtration.	Heavy loam overlying stiff clay.	42,800	8,500
Provisional Standards - -	Less than 100,000 per c.c.	Less than 10,000 per c.c.	Less than 1,000 per c.c.	Less than 10 per c.c.	Negative result ·1 c.c.	Negative result ·1 c.c.	Provisional Standards.			

It must be remembered that averages are sometimes misleading and that a few really bad effluents may so alter the average figures as to make the majority of effluents from a sewage farm appear worse than was actually the case. The above summary should be read in relation to the detailed statements made in Sections I. to VIII., Part III. (Bacteriological Report).

From the foregoing summary, it is evident that if the effluents did not on the average pass the standards§ set up for the various tests, they all showed a high percentage degree of purification. In most cases, the farms were treating too much sewage per acre either actually or relatively to the character of the soil. Given a fair proportion between (1) the volume and character of the sewage to be "treated," and (2) the effective purifying area of the farm and the suitability of the soil for purification purposes, there can be little doubt that the effluents which could be produced from land would easily pass the suggested standards. If the standards were made ten times more lenient, *a concession not perhaps unduly great from the bacteriological point of view in connection with non-drinking water streams*, all the effluents would then pass the modified standards with the exception of those from Beddington (with regard to the total number of microbes present). In future, it will be convenient to refer to this modified conception of the original ("primary") standards as "secondary" standards. Nevertheless, when it is remembered how easily the best effluents from each sewage farm "passed" the primary standards; how near, comparatively speaking, the average effluents were to "passing"; and how large was the volume of sewage being treated (either actually or relatively to the suitability of the soil for sewage purification purposes), it cannot well be contended that the standards provisionally suggested for working purposes are of a drastic and wholly impracticable nature.

The question may be asked "Are filtration effluents immeasurably better from the bacteriological point of view than surface irrigation effluents?" This is, for many reasons, a difficult question to answer. Apart from the difference in the kind of treatment (filtration as compared with surface irrigation), other factors, the effect of which cannot readily be estimated, varied to a considerable extent. For example, the volume and character of the sewage being treated per acre; the extent and nature of cropping operations; the drainage arrangements; the mode of treatment; the management of the farm; the question of storm water; and other variable factors.

There was certainly no comparison between the Nottingham sandy loam filtration effluents and the effluents from any of the other sewage farms that were examined. Excluding Nottingham, the filtration effluents from Aldershot Camp (sand), Cambridge (sandy loam), and Altrincham (peaty and sandy soil) were not conspicuously better than those obtained from Beddington (surface irrigation with some filtration; gravelly loam), Leicester (surface irrigation and filtration combined; clayey soil), South Norwood (surface irrigation and a little filtration; clayey soil), and Rugby (surface irrigation and filtration combined; heavy loam). Cambridge, however, was treating at one time* a very large amount of sewage (121,600 gallons per acre per 24 hours), and the character of the soil on Aldershot Camp and Altrincham sewage farms was not that best suited for treating large volumes of sewage by filtration methods. On the other hand, Beddington and Rugby farms also were treating at one time large volumes of sewage, 57,100 and 42,800 gallons per acre per 24 hours respectively.

The variable factors above alluded to make it extremely difficult to compare land of different kinds. It would not for example be fair to compare the results obtained from Nottingham (light loam; filtration), with those from Rugby (heavy loam; combined surface irrigation and filtration), since the latter was treating at one time nearly twice as much sewage as the former

§ It must be definitely understood that these standards are merely provisional and are used for comparative purposes only.

* It must be remembered that the volume of sewage treated per acre *at one time* is a different thing from the volume of sewage treated per acre reckoned on the year's working of the total irrigable area. The former figures are arrived at by dividing the dry weather flow of sewage by the average area at one time under irrigation ("working area"). The latter figures, by dividing the dry weather flow of sewage by the total irrigable area ("working" and "resting" areas). As the ratio between the "working" and "resting" areas varied considerably at the different sewage farms, this is a point of considerable importance. The two sets of figures are placed side by side for comparative purposes in the preceding table.

(Rugby, 42,800; Nottingham, 23,300 gallons per acre per 24 hours respectively). Conversely, the amount of sewage being treated at one time at Cambridge (filtration) was ten times greater than that treated at South Norwood (combined surface irrigation and filtration), the former being a sandy loam overlying gravel and sand, and the latter a modified clay resting on London clay (Cambridge, 121,600; South Norwood, 12,000 gallons per acre per 24 hours respectively). The results were bacteriologically not widely dissimilar in the two cases, although the South Norwood effluents were on the whole the better, and so, as a conjecture, it may be said that sandy loam can "treat" much larger volumes of sewage than a clay soil. If we compare Leicester (stiff clay; combined surface irrigation and filtration) with Nottingham (light loam; filtration), both farms treating at one time per acre approximately equal amounts of sewage (21,500 and 23,300 gallons per acre per 24 hours respectively), we do indeed find that the bacteriological results differed to a conspicuous extent in the two cases, the latter yielding exceptionally good effluents, and the former effluents only moderately good.

Further, Beddington (gravelly loam; combined surface irrigation and filtration), yielded on the whole worse results than Cambridge (sandy loam; filtration), although treating at one time only half the amount of sewage (57,100 and 121,600 gallons per acre per 24 hours respectively). Here, however, the difference in the results is to be ascribed to the different methods of treatment (combined surface irrigation and filtration at Beddington; filtration at Cambridge), rather than to the different nature of the soil in the two cases.

Perhaps the most useful lesson to be learnt from the results is that land even of unsuitable quality for sewage purification purposes, and used mainly as a surface irrigation farm, can yield moderately good effluents.

The difference in (1), the character of the sewage; (2), the volume of sewage treated per acre; (3), the nature of the soil; and (4), the method of treatment employed at the different sewage farms no doubt accounts for the fact that, excluding Nottingham, the average bacteriological composition of the effluents from the different sewage farms was not widely dissimilar.

The practical side of the question is dealt with in a separate Section.

6. *Is the treatment of sewage on land to be preferred to its treatment by artificial processes, as at present conducted,* e.g., *contact beds, continuous filters, etc.?*

The artificial processes are still under investigation, and it is perhaps not desirable at present to express any definite opinion on this question.

Artificial processes are still in the experimental stage, and for the most part they have been worked rather with a view to treating as large an amount of sewage as possible, compatible with producing a non-putrescible effluent, than with a view to producing an effluent of the greatest purity.

Worked in the way which has been usually adopted, the effluents from these processes, as judged bacteriologically, are not equal to the effluent from land of average suitability. But there seems no reason to assume that these effluents might not be brought up to any reasonable standard required, possibly either by working the process at a much slower rate, or by subsequently passing the effluent through some special filter, or by chemically treating it.

7. *What degree of biological modification does the sewage undergo as the result of its treatment on land?*

So far as the actual results are concerned, the effluents show no very appreciable biological modification, beyond a reduction in the number of bacteria which they contain.

It must, however, be remembered that the media and particular processes employed in the investigation might fail to demonstrate biological modifications in cases where such modifications really existed. For example, the mere presence of oxidised nitrogen in an effluent is a practical proof of the multiplication of the nitroso- and nitro-bacteria. No doubt these are largely retained in the soil, but it is probable that their number in the effluent is *relatively* greater than in the crude sewage. (*See* Conclusions, Part III., Bacteriological Report.)

8. *The biological condition of the rivers or brooks into which effluents are being discharged.*

This is a question which must needs have some bearing on the choice of standards.

The effluents from Aldershot Camp, Altrincham, Cambridge, Beddington, (Croydon), Leicester, South Norwood, Nottingham, Rugby and Worsley sewage farms discharge into the River Blackwater, Sinderland Brook, River Cam, River Wandle, Anstey Brook (flowing into River Soar), Chaffinch Beck, River Trent, River Avon and Worsley (Parrin) Brook, respectively.

All these rivers or streams were impure, many of them very impure above the effluent outfalls. The chief results are shown in the following table

Description of the Samples.		Total number of bacteria per c.c.		Number of B. coli (or closely allied forms) per c.c.	Number of spores of B. enteritidis sporogenes (Klein's "enteritidis change" in milk culture) per c.c.	Remarks.
		Gelatine at 20° C.	Agar at 37° C.			
Aldershot Camp - -	57. Blackwater river water above junction with effluent 27th March, 1900	8,200	500	At least 10 (Indol test, + ·1 c.c.)	At least 10.	"Gas" test, + 1 − ·1 c.c.
- - -	326. As above 24th July, 1901	—	—	—	At least 10, but less than 100.	Neutral red broth test, + ·01, − ·001 c.c. Litmus milk test, acid clot, + ·1 c.c. "Gas" test, + ·1, − ·01 c.c.
Altrincham - - -	71. Sinderland brook water above effluent outfall 7th May, 1900	53,000	6,700	At least 100 (Indol test, + ·01 c.c.)	At least 10, less than 100.	"Gas" test, + ·1, − ·01 c.c.
Cambridge - - -	222. Cam river water above effluent outfalls - 6th February, 1901	38,000	1,400	10, not 100 (Indol test, + ·1, − ·01 c.c.)	At least 1, less than 10.	"Gas" test, − 1 c.c.
Beddington - - -	45. Wandle river water above effluent outfalls 26th November, 1900	72,000	2,680	10, not 100 (Indol, + ·1 c.c.)	+ 10 c.c. − 1 c.c.	—
Leicester - - - -	133. Anstey brook water above effluent outfalls 3rd December, 1900	540,000	71,000	1, not 10 (Indol, + 1 c.c.)	None in 1 c.c.	—
South Norwood - -	32. Chaffinch Beck water above effluent outfalls 30th January, 1900	7,900	1,100	100, not 1000 (Indol, + ·01 c.c.)	+ 10 c.c. − 1 c.c.	—
Nottingham - - -	120. Trent river water above effluent outfalls 6th August, 1900	—	3,300	100, not 1,000 (Indol, + ·001 c.c.)	At least 1, but less than 10.	—
Rugby - - - -	105. Avon river water above effluent outfalls 9th July, 1900	156,000	7,100	At least 100.	Negative, 10 c.c.	"Gas" test, + 1, − ·1 c.c.
Worsley - - - -	284. Worsley (Parrin) brook water above effluent outfalls 20th May, 1901	304,000	41,500	100 (Indol test, + ·01 c.c.)	At least 1, but less than 10.	—

Except in a few cases as regards individual tests, none of these samples would be rejected according to the proposed bacteriological standards for non-drinking water streams; but, of course, they would all be regarded as most impure biologically from the point of view of drinking water streams.

As regards the biological quality of the samples of mixed effluent and river water, Part II. (Bacteriological Report) must be consulted.

9. *The biological quality of the subsoil water in the neighbourhood of sewage farms.*

As a good deal of subsoil water usually finds its way into the sewers and may also gain access to the under drains on the sewage farms, it was considered advisable to examine a few samples of subsoil water. The following is a brief summary of the results :—

	Description of the sample.	Total number of bacteria per c.c.		Number of B. coli (or closely allied forms) per c.c.	Number of spores of B. enteritidis sporogenes (Klein's "Enteritidis change" in milk culture) per c.c.	Remarks.
		Gelatine at 20°C.	Agar at 37°C.			
Aldershot	60. Subsoil water. 2nd April, 1900. Pump well near farm.	720	38	None in 1 c.c. (Indol test, + 1 c.c.)	None in 10 c.c.	"Gas" test, negative result, 1 c.c. [Apparently no chance of contamination from the farm.]
Altrincham	78. Subsoil water. 16th May, 1900.	1,200	253	None in 1 c.c. (Indol test, + 1 c.c.)	+10, −1 c.c.	"Gas" test, negative result, 1 c.c. [Land under irrigation about 150 yards distant]
Cambridge	219. Subsoil water. 30th January, 1901. Taken from land drain in vicinity of farm.	4,300	230	None in 1 c.c. (Indol test, +1, −·1 c.c.)	−1 c.c.	"Gas" test, negative result, 1 c.c. [Apparently no chance of contamination from the farm.]
Leicester	5. Subsoil water. 15th November, 1899. From high portion of farm; sewaged land within 50 yards.	1,320,000	89,000	100, less than 1,000	−10 c.c.	[*Freshly dug well; results inconclusive.*]
Luton	242. Well water. Well 20 feet deep. 19th March, 1901.	40,000	410	At least 10 (Indol test, + ·1 c.c.)	−10 c.c.	[Below Luton farm; liable to surrounding soil pollution from contents of tub closets used as manure.]
	244. As above. 27th March, 1901.	800	266	None in 1 c.c. (Indol test, + 1 c.c.)	−10 c.c.	
	410. As above. 7th November, 1902.	52,000	2,090	1 not 10 (Indol test, − 1 c.c.)	−1 c.c.	
Andover	415. Shallow well water. 13th November 1901. Dr. Vivian Poore's experiment.	1,400	280	1 but less than 10 (Indol test, +1 −·1 c.c.)	−1 c.c.	Neutral red broth test, + ·1 c.c. [Surrounding land manured with excremental matters.]

The results varied considerably, but, excluding the worst samples, were very good. The best samples were seemingly fit for drinking purposes on the basis of the results obtained, apart from a knowledge of their source. But in judging waters from the point of view of potability, a more elaborate method of analysis (Pasteur filter-brushing method) is necessary than was carried out in the present instance. The results of two years' work for the Local Government Board on the chemical and biological characters of the Chichester well waters showed that shallow wells sunk in soil and subsoil, known to have been polluted and still liable to be contaminated, may sometimes yield good results when examined by the ordinary chemical tests, and yet show on *searching* bacteriological examination unequivocal evidence of excremental pollution.

10. *The biological qualities of samples of* (1) *storm water and of* (2) *"street washings."*

(1) As is well known, sewage when diluted with rain water is at times discharged by means of storm overflows into rivers in the "untreated" condition. For practical reasons it may be impossible to insist on the treatment of more than a few times the dry weather flow of sewage. But it should be remembered that sewage diluted even six or more times with pure water would still remain a liquid almost as potentially dangerous to health as normal crude sewage.

During the course of the investigation we were only able to collect a few samples of storm water. But since then a fair number of samples have been examined from other places and the results obtained confirm the truth of the above statements.

(2) As regards "street washings" (separate system), it has been perhaps too readily assumed in the past that the storm liquid resulting from the adoption of the separate system is relatively unobjectionable. From the bacteriological point of view, this liquid may be grossly and dangerously (potentially speaking) impure.

The following is a brief summary of the chief results :—

	Description of Sample.	Total number of bacteria per c.c.		Number of B. coli (or closely allied forms) per c.c.	Number of spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anaerobic milk culture) per c.c.	Remarks.
		Gelatine at 20°C.	Agar at 37°C.			
ALTRINCHAM.	67. Storm water overflow after running for 30 minutes, April 29th, 1900	17,600,000	1,480,000	100,000 (Indol test, + ·00001 c.c.)	At least 100, but less than 1,000	"Gas" test, + ·01, – ·001 c.c. 2 c.c. were injected subcutaneously into a guinea-pig. The animal died on the third day.
	68. Same as above, after the overflow had been working 1½ hours	26,100,000	1,640,000	10,000 not 100,000 (Indol test, + ·00001 c.c.)	At least 100, but less than 1,000	"Gas" test, + ·001, – ·0001 c.c. 2 c.c were injected subcutaneously into a guinea-pig. The animal died on the third day.
ALDERSHOT	311. Street "washings," 2nd July, 1901, after 2 days' heavy rainfall	7,500,000	640,000	—	At least 10, but less than 100	Neutral red broth test, + ·0001, – ·00001 c.c. Litmus milk test, acid clot ·001 c.c. "Gas" test, + ·001, – ·0001 c.c.
	314. As above, but after 3 days' heavy rain, slightly contaminated with sewage from the farm	22,800,000	900,000	—	At least 100, but less than 1,000	Neutral red broth test, + ·00001 c.c. Litmus milk test, acid clot ·0001 c.c. "Gas" test + ·001, – 0001 c.c.
SOUTH NORWOOD.	174. Street "washings," 14th November, 1900	1,470,000	88,000	At least 10 (Indol test, + ·1 c.c.)	At least 100, but less than 1,000	"Gas" test, + ·1, – ·01 c.c.
	179. As above, 21st November, 1900	3,840,000	293,000	10,000 not 100,000 (Indol test, + ·00001 c.c.)	At least 10, but less than 100	"Gas" test, + ·01 c.c
	182. As above, after running 2 hours, 28th November, 1900	13,700,000	154,000	10,000 (Indol test, + ·0001 c.c.)	At least 100, but less than 1,000	
	188B. As above, after running 4 hours, 1st December, 1900	9,900,000	380,000	1,000 (Indol test, + ·001 c.c.)	At least 100, but less than 1,000	"Gas" test, + ·1, – ·01 c.c. A guinea-pig inoculated with 2 c.c. of this sample died on the second day.
RUGBY.	96A. Street "washings," 20th June, 1900	15,900,000	94,000	10,000 (Indol test, + ·0001 c.c.)	At least 10, but less than 100	"Gas" test, + ·01, – 001 c.c. 2 c.c. of the sample proved fatal on subcutaneous injection into a guinea-pig.
	231. Street "washings," 4th March, 1901	930,000	12,400	1,000 (Indol test, + ·001 c.c.)	At least 100, but less than 1,000	"Gas" test, – ·1 c.c. Neutral red broth test, + ·01, – ·001 c.c. Litmus milk test, + ·01, – ·001 c.c. A guinea-pig inoculated with 4 c.c. of the same sample died on the second day.

It is obvious from the above table that storm overflow and "street washings" liquids may be of a grossly impure character and certainly quite unfit for discharge into drinking water rivers. The samples were, generally speaking, not in a fit condition for discharge even into non-drinking water streams, according to the provisional biological standards of purity.

Lastly, it is to be hoped that the foregoing conclusions will be interpreted in the light of the more detailed and guarded statements given in Part III. (Bacteriological Report).

SECTION VII.

COMPARISON BETWEEN THE CHEMICAL AND BACTERIOLOGICAL RESULTS.*

1. *General Comparison and Conclusions.*

In comparing the chemical and bacteriological results, it is advisable in the first place to give a tabular statement showing side by side (1) the statistics relating to each of the eight sewage farms kept under detailed observation; (2) the bacteriological results; (3) the chemical results; and (4) the main conclusions to be drawn from our chemical and bacteriological investigations.

It must be understood that in the necessarily brief summary which follows, many points are omitted which may be of considerable importance.

It is to be hoped, however, that the following statement will be read in the light of the results set forth in detail in Parts II. and III. (Chemical and Bacteriological Reports).

* *Note.*—In this section the farms follow one another in alphabetical order.

ALDERSHOT CAMP

Statistical Information.		Bacteriological Results (Average Results per c.c.).
1. Situation of farm	Ashvale, near Camps.	*Total number of bacteria* (gelatine at 20° C.):—183,266 (99 per cent. reduction). *Primary standard*, less than 100,000. *Secondary standard*, less than 1,000,000.*
2. Total acreage of farm	138·5 acres.	*Total number of bacteria* (agar at 37° C.):—37,308 (99 per cent. reduction). *Primary standard*, less than 10,000. *Secondary standard*, less than 100,000.
3. Total irrigable area	120·5 acres.	*B. coli*‖:—At least 1,000, but less than 10,000. *Primary standard*, less than 1,000. *Secondary standard*, less than 10,000.§
4. Average area irrigated at one time	About 40 acres.	*B. enteritidis sporogenes test*:—At least 10, but less than 100 per c.c. *Primary standard*, less than 10. *Secondary standard*, less than 100.§
5. Population draining to farm	20,000.	"*Gas*" *test*:— + 1 c.c.; — ·1 c.c. *Primary standard*, negative result, ·1 c.c. *Secondary standard*, negative result, .01 c.c.§
6. Population per acre irrigated	166.	*Neutral red broth test*:— + ·001; — ·0001 c.c. *Primary standard*, negative result — ·001 c.c. *Secondary standard*, negative result, ·0001 c.c.§
7. Gallons of sewage per head per day	50.	None of the effluents were in a fit state to be discharged into a drinking-water stream.
8. Dry weather flow of sewage per 24 hours	1,000,000 gallons.	The effluents, on the average, came within measurable distance of passing the primary standards laid down for non-drinking-water streams.
9. Gallons of sewage (exclusive of storm water) treated per acre per 24 hours	25,000.	The best effluents were remarkably satisfactory, and far more than passed the standards set up for the above tests.
10. Gallons of sewage treated per acre per 24 hours on the assumption that each acre of the irrigable area is under sewage all the time	8,300.	The effluents judged by the B. enteritidis sporogenes test were usually less satisfactory than when judged by the "gas" test.
11. Character of the sewage	Purely domestic.	Speaking in general terms, the effluents may be said to have been at least 100 times purer than the sewage, and to have passed successfully the *secondary* standards suggested for non-drinking-water streams.
12. Method of treatment	Screening, settling tanks, and filtration.	For further information reference must be made to Section I., Part III. (Bacteriological Report).
13. General character of the soil and subsoil	Sand.	
14. Separate or combined sewerage system	Separate.	
15. The final effluent is discharged into	River Blackwater.	
16. Number of years farm in operation before 1900	36 years.	

* It must be definitely understood that these standards are merely provisional and are used for comparative purposes only.

‖ Inclusive of gas-forming coli-like microbes. This remark also applies to the effluents from Altrincham, Cambridge, Beddington (Croydon), Leicester, South Norwood, Nottingham and Rugby Sewage Farms.

§ These averages are only approximate.

SEWAGE FARM EFFLUENTS.

Chemical Results.

The analysis of 16 to 18 old land and general effluents* gave the following figures, among others :—

	Parts per 100,000. Average.
Total nitrogen (3·69 to 8·99) -	- 6·0
Ammoniacal nitrogen (0·91 to 4·98)	- 1·85
Albuminoid ,, (0·12 to 0·47)	- 0·26
Nitric + nitrous ,, (0·0 (?) to 5·97)	- 3·21
"Oxygen absorbed" from permanganate in 4 hours at 26·7° C. (80° F.) (1·02 to 5·68) - - -	- 2·72

Incubator test (smell): 16 samples out of 18 passed.

Percentage purification on the chance and hourly samples of sewage :—

	Chance. Per cent.	Hourly. Per cent.
(*a*) Calculated on the albuminoid nitrogen - - - -	94	84
(*b*) Calculated on the "oxygen absorbed" - - -	90	87

The Aldershot Camp Farm effluents may be described as highly nitrated effluents from a very strong sewage which has undergone a relatively, but not an absolutely, high degree of purification. The samples examined were more or less yellow or brown in colour, but colourless or light yellow when filtered, and they contained decided amounts of *exceedingly flocculent* light brown suspended solids, *i.e.*, fragments of weed coated with oxide of iron,† washed from the drain-pipes. This weed, of course, supplied some of the albuminoid nitrogen of the analysis. Excepting in two instances, the smell of the samples was clean when they came to be analysed. Being percolation effluents, and not purified to an absolute high standard like the effluents at Nottingham, the amount of dissolved oxygen present was not large. The marked increase in concentration of these effluents in summer is striking (see curves in Aldershot Camp Farm Report, Part II.). In conclusion, though some or most of the effluents still contained considerable amounts of organic matter, not much of this was of a fermentable character, under laboratory conditions of experiment, and the nitrate present was always much more than sufficient to keep them sweet.

For details, see the Chemical Report on the Aldershot Camp Farm and the Section upon Soils (Part II.).

* Some of these contained admixed effluent from newly laid-out land, which was of much less good quality than the ordinary old land effluent.

† Strictly speaking, this is no doubt a basic carbonate of iron.

Remarks.

. The sewage (purely domestic) is strong.

It cannot be said that for a filtration farm Aldershot Camp was treating a *large volume* of sewage, either per acre of the "working" daily irrigable area, or per acre of the total irrigable area; but it was treating, both actually and relatively, a *large quantity* of organic matter (*see* diagram 5, Section II., Subsection 11). Moreover, the soil and subsoil (coarse sand over very fine sand) are not of the best kind for purifying a large volume of sewage, and the average filtration depth down to the drains is only about 3 feet (compare Section II., Subsection 13).

The sewerage system is separate, so the farm is not called upon to treat much storm water.

On the whole we consider that 25,000 gallons per acre per 24 hours (8,300 gallons per acre of the total irrigable acre per 24 hours) is too large a volume of a strong sewage to be treated by screening, settling, and filtration through about 3 feet of sand of the above nature, if completely and uniformly satisfactory effluents are to be expected, but not too large a volume of sewage per acre to yield effluents showing a high percentage (possibly even a sufficient relative degree) of purification.

Statistical Information.		Bacteriological Results (Average Results per c.c.).
1. Situation of farm	Near Carrington Moss, 2 miles from Altrincham.	*Total number of bacteria* (gelatine at 20° C.):—363,400 (99 per cent. reduction). *Primary standard*, less than 100,000. *Secondary standard*, less than 1,000,000.*
2. Total acreage of farm	75·5 acres.	*Total number of bacteria* (agar at 37° C.):—7,275 (99 per cent. reduction). *Primary standard*, less than 10,000. *Secondary standard*, less than 100,000.
3. Total irrigable area	35 acres.	*B. coli*:—At least 100, but less than 1,000. *Primary standard*, less than 1,000. *Secondary standard*, less than 10,000.§
4. Average area irrigated at one time	17·5 acres.	*B. enteritidis sporogenes test*:—At least 1, but less than 10. *Primary standard*, less than 10. *Secondary standard*, less than 100.§
5. Population draining to farm	18,000.	"*Gas*" *test*:— + 1 c.c.; — ·1 c.c. *Primary standard*, negative result with ·1 c.c. *Secondary standard*, negative result, .01 c.c.§
6. Population per acre irrigated	514.	*Neutral red broth test*:— + ·01 c.c.; — ·001 c.c. *Primary standard*, — ·001 c.c. *Secondary standard*,—·0001 c.c.§
7. Gallons of sewage per head per day	44·4.	None of the effluents were in a fit state to be discharged into a drinking-water stream.
8. Dry weather flow of sewage per 24 hours	800,000 gallons.	The effluents, on the average, passed the provisional standards laid down for non-drinking water streams, except as regards the total number of bacteria (*gelatine at* 20° *C.*) present.
9. Gallons of sewage (exclusive of storm water) treated per acre per 24 hours	46,000.	Speaking in general terms, the effluents may be said to have been from 100 to 1,000 times purer than ordinary sewage, and at least 100 times purer than Altrincham sewage, which is, however, a weak sewage.
10. Gallons of sewage treated per acre per 24 hours on the assumption that each acre of the irrigable area is under sewage all the time	23,000.	For further information reference must be made to Section II., Part III. (Bacteriological Report).
11. Character of the sewage	Domestic.	
12. Method of treatment	Settling tank and land filtration.	
13. General character of the soil and subsoil	Peaty soil lying upon sand and gravel.	
14. Separate or combined sewerage system	Combined.	
15. The final effluent is discharged into	Sinderland Brook.	
16. Number of years farm in operation before 1900	30 years.	

* It must be definitely understood that these standards are merely provisional and are used for comparative purposes only.

§ These averages are only approximate.

SEWAGE FARM EFFLUENTS.

Chemical Results.	Remarks.
Out of 14 to 18 effluents analysed, the following figures, among others, were obtained:—	The sewage (domestic) is weak.
Parts per 100,000. Average.	Even for a filtration farm Altrincham was treating a *large volume* of sewage, both per acre of the "working" daily irrigable area, and per acre of the total irrigable area; and although the sewage was weak, the farm was treating in the aggregate, so far as our data suffice for a comparison, a large quantity of organic matter, although not so much as at Cambridge. The soil and subsoil (porous peaty soil lying upon sand admixed with a little gravel) are not *apparently* of the best kind for purifying a large volume of sewage, especially when the average filtration depth downwards to the drains (only about 3 ft. 9 in.) is taken into consideration (compare Section II., Subsection 13). At the same time, the results which we have obtained from Altrincham lead us to consider, so far as our data go, that the aëration through the soil and subsoil must be better than would at first sight appear.
Total nitrogen (1·36 to 4·99) - - 2·22 Ammoniacal nitrogen (0·65 to 1·87) - 1·23 Albuminoid ,, (0·07 to 0·25) - 0·13 Total organic ,, (0·10 (?) to 0·45) 0·26 Nitric + nitrous nitrogen (0·0 to 3·64) 0·76 "Oxygen absorbed" from permanganate in 4 hours at 26·7° C. (80° F.) (0·92 to 2·65) - - - - - - - 1·75	
Incubator test (smell): 13 out of 16 samples passed.	
Percentage purification on the chance samples of sewages and lagoon liquors taken together (this calculation is *very approximate*):—	
Per cent. (*a*) Calculated on albuminoid nitrogen - 79 (*b*) ,, ,, "oxygen absorbed" - 67	
These effluents contained varying amounts of red-brown flocculent matter (no doubt to a considerable extent basic ferric carbonate) which gave to many of them a deep brown colour and a turbid appearance. After being filtered, some of the effluents were just tinged, but others remained very brown. They had either no smell at all or an iron smell when they came to be analysed. The presence of so much iron in the sandy subsoil no doubt accounts to some extent for the comparatively small quantity of dissolved oxygen found in the effluents.	The combined sewerage system is in operation but the farm does not treat much storm water.
Speaking generally, the Altrincham effluents were fairly satisfactory on the whole, but the oxidized nitrogen was, *as a rule*, low in proportion to the total nitrogenous matter present. It is worth noting that the effluents from the uncropped arable land were the least nitrated. For details see the Chemical Report on the Altrincham Farm (Part II).	The bacteriological results, apart from the total number of bacteria (gelatine at 20° C.), do not admit of the conclusion that 46,000 gallons per acre (23,000 gallons per acre of the total irrigable area) is too large a volume of a weak sewage to be treated by settling and filtration through a peaty soil lying upon sand and gravel (that is, where the effluent is discharged into a non-drinking water stream). The chemical results indicate that the land at present is somewhat overtaxed, and that with a smaller dose of sewage the results would be distinctly good.

Statistical Information.		Bacteriological Results (Average Results per c.c.).
1. Situation of farm	3 miles from Cambridge.	*Total number of bacteria* (gelatine at 20° C.):—711,476 (94 per cent. reduction). *Primary standard*, less than 100,000. *Secondary standard*, less than 1,000,000.*
2. Total acreage of farm	102·5 acres.	*Total number of bacteria* (agar at 37° C.):—78,327 (94 per cent. reduction). *Primary standard*, less than 10,000. *Secondary standard*, less than 100,000.
3. Total irrigable area	74 acres.	*B. coli*:—At least 1,000, but less than 10,000. *Primary standard*, less than 1,000. *Secondary standard*, less than 10,000.§
4. Average area irrigated at one time	18·5 acres.	*B. enteritidis sporogenes test*:—At least 10, but less than 100. *Primary standard*, less than 10. *Secondary standard*, less than 100.§
5. Population draining to farm	50,000.	"*Gas*" *test*:— + ·1 c.c.; — ·01 c.c. *Primary standard*, — ·1 c.c. *Secondary standard*, — ·01 c.c.§
6. Population per acre irrigated	675.	None of the effluents were in a fit state to be discharged into a drinking-water stream.
7. Gallons of sewage per head per day	45.	The effluents failed to pass the primary, but passed successfully the secondary standard for non-drinking-water streams.
8. Dry weather flow of sewage per 24 hours	2,250,000 gallons.	Speaking in general terms, the effluents may be said to have been about 100 times purer than crude sewage.
9. Gallons of sewage (exclusive of storm water) treated per acre per 24 hours	121,600.	For further information reference must be made to Section III., Part III. (Bacteriological Report).
10. Gallons of sewage treated per acre per 24 hours on the assumption that each acre of the irrigable area is under sewage all the time	30,400	* It must be definitely understood that these standards are merely provisional and are used for comparative purposes only. § These averages are only approximate.
11 Character of the sewage	Mainly domestic (some brewery refuse).	
12. Method of treatment	Screening and settling tank and land filtration.	
13. General character of the soil and subsoil	Sandy loam overlying gravel and sand.	
14. Separate or combined sewerage system	Partially separate.	
15. The final effluent is discharged into	River Cam.	
16. Number of years farm in operation before 1900	5 years (systematic) working.	

SEWAGE FARM EFFLUENTS.

Chemical Results.

From the analysis of 17 to 18 effluents, the following figures, among others, were obtained :

	Parts per 100,000. Average.
Total nitrogen (1·48 to 3 19) -	2·09
Ammoniacal nitrogen (0·22 to 1·31) -	0·65
Albuminoid ,, (0·04 to 0·18) -	0·09
Total organic ,, (0·04 (?) to 0·42) -	0·21
Nitric + nitrous nitrogen (0·69 to 2·25) - - - - - -	1·26
"Oxygen absorbed" from permanganate in 4 hours at 26·7° C. (80°F.) (0·16 to 1·31) - - - - - -	0·81

Incubator test (smell) : 17 out of 18 samples passed.

Percentage purification on the chance and hourly samples of sewage :—

	Chance. Per cent.	Hourly. Per cent.
(*a*) Calculated on the albuminoid nitrogen - - - -	85	90
(*b*) Calculated on the "oxygen absorbed" - - -	88	92

The Cambridge effluents were partly clear and colourless, partly slightly opalescent and of a brown tinge and containing a little flocculent matter, partly rather turbid from the separation of carbonate of lime. They had a clean smell when analysed. The dissolved oxygen was never high, both because of these being percolation effluents, and because in some of the less purified samples the organic matter was of a somewhat fermentable character, though in every case excepting one there was enough nitrate present to prevent putrescence upon incubation. It will be noted here that we are dealing with an effluent from a dilute sewage. To sum up, the effluents were usually good from a chemical point of view, and in some instances very good.

Full details are given in the Chemical Report on the Cambridge Farm and in the Section dealing with Soils (Part II.)

Remarks.

The sewage (mainly domestic) is rather weak, and is treated for the most part on uncropped land. In this respect the Cambridge Farm differs from the others.

Even for a filtration farm Cambridge was treating an *exceptionally large volume* of sewage, both per acre of the "working" daily irrigable area and per acre of the total irrigable area. It was also treating in the aggregate a large amount of organic matter (*see* diagram 5, Section II., Subsection 11), but it must be remembered that this organic matter was highly diluted. Nevertheless, the soil and subsoil (sandy loam overlying gravel and sand), like those at Nottingham, are admirably adapted for the purification of a large volume of sewage, and the average filtration depth down to the drains is nearly 5 feet (compare Section II., Subsection 13).

The sewerage system is partially separate, and very little storm water reaches the farm.

In conclusion, we consider that 121,600 gallons per acre per 24 hours (30,400 gallons per acre of the total irrigable area per 24 hours) is rather too large a volume of even a weak sewage to be treated by screening, settling, and filtration through even 5 feet of a soil and subsoil admirably adapted for purification purposes. It should be borne in mind here that it is easier to bring a weak sewage down to an absolute standard of purity (such, for example, as the Mersey and Irwell) than a strong sewage (volume for volume), although in the former case the liquid has really undergone less purification (compare Part II., Chemical Report, Section on Standards).

BEDDINGTON (CROYDON)

Statistical Information.		Bacteriological Results (Average Results per c.c.).
1. Situation of farm	3 miles from Croydon.	*Total number of bacteria* (gelatine at 20° C.):—1,413,200 (95 per cent. reduction). *Primary standard*, less than 100,000. *Secondary standard*, less than 1,000,000.*
2. Total acreage of farm	673·5 acres.	*Total number of bacteria* (agar at 37° C.):—112,000 (97 per cent. reduction). *Primary standard*, less than 10,000. *Secondary standard*, less than 100,000.
3. Total irrigable area	420 acres.	*B. coli*:—At least 1,000, but less than 10,000. *Primary standard*, less than 1,000. *Secondary standard*, less than 10,000§.
4. Average area irrigated at one time	About 70 acres.	*B. enteritidis sporogenes test*:—At least 10, but less than 100. *Primary standard*, less than 10. *Secondary standard*, less than 100§.
5. Population draining to farm	100,000.	"*Gas*" *test*:— + ·1 c.c.; — ·01 c.c. *Primary standard*, — ·1 c.c. *Secondary standard*, — ·01 c.c.§.
6. Population per acre irrigated	238.	*Neutral red broth test*:— + ·001 c.c.; — ·0001 c.c.; *Primary standard*, — ·001 c.c. *Secondary standard*, — ·0001 c.c.§.
7. Gallons of sewage per head per day	40.	None of the effluents were in a fit state to be discharged into a drinking-water stream.
8. Dry weather flow of sewage per 24 hours	4,000,000 gallons.	The effluents failed to pass the primary, but passed successfully (except as regards total number of bacteria) the secondary standards for non-drinking-water streams.
9. Gallons of sewage (exclusive of storm water) treated per acre per 24 hours	57,100.	Speaking in general terms, the effluents may be said to have been at least from 10 to 100 times purer than crude sewage.
10. Gallons of sewage treated per acre per 24 hours on the assumption that each acre of the irrigable area is under sewage all the time	9,500.	For further information reference must be made to Section IV., Part III. (Bacteriological Report).
11. Character of the sewage	Almost purely domestic.	
12. Method of treatment	Screening, surface irrigation and filtration.	
13. General character of the soil and subsoil	Gravelly loam over gravel and sand	
14. Separate or combined sewerage system	Partially separate.	
15. The final effluent is discharged into	River Wandle.	
16. Number of years farm in operation before 1900	39 years.	

* It must be definitely understood that these standards are merely provisional and are used for comparative purposes only.

§ These averages are only approximate.

SEWAGE FARM EFFLUENTS.

Chemical Results.

The analysis of 15 to 16 effluents* yielded the following figures :—

	Parts per 100,000. Average.
Total nitrogen (1·02 to 3·49) - -	2·20
Ammoniacal nitrogen (0·23 to 3·10) -	1·48
Albuminoid ,, (0·06 to 0·23)	0 14
Nitric + nitrous nitrogen (0·03 to 1·43) - - - - - -	0·37
"Oxygen absorbed" from permanganate in 4 hours at 26·7° C. (80°F.) (0·90 to 2·09) - - - - - -	1·41

Incubator test (smell) : 11 out of 15 samples passed.

Percentage purification on the chance and hourly samples of sewage :—

	Chance. Per cent.	Hourly. Per cent.
(*a*) Calculated on the albuminoid nitrogen - - - -	92	89
(*b*) Calculated on the "oxygen absorbed" - - -	90	89

These effluents varied a good deal in appearance, some being clear and almost colourless ; others of a yellowish to brownish tint, with but a very small amount of suspended solids ; others turbid, with very considerable quantities of solids in suspension. Three-fourths of them, however, might be taken as very free from the latter. All excepting one or two had a clean smell when analysed. The dissolved oxygen varied very much, but half of the effluents were well aerated on the day of analysis—a strong point in their favour. The ammoniacal nitrogen was high, and the nitric nitrogen low ; still, where nitrate was present, it was not reduced to any extent upon jointing or incubating the samples.

The sewage at Beddington is of medium strength. The farm is capable of producing by surface irrigation a high-class effluent, chemically speaking, and does so sometimes, but not always. The results obtained in the special experiment demonstrate the high purifying power of the Beddington soil and subsoil when used for filtration.

For details, see the Chemical Report on the Beddington Farm and the Section upon Soils in Part II.

* Of the final effluents two were over two fields only.

Remarks.

The sewage (almost purely domestic) is of medium strength.

For a combined surface irrigation and filtration farm, Beddington was treating a very large volume of sewage per acre of the "working" daily irrigable area, and also a large volume per acre of the total irrigable area. As regards organic matter, it was treating a little less than Rugby in the aggregate, owing to the sewage being much weaker (*see* Diagram 5, Section II., Subsection 11).

The soil and subsoil (light gravelly loam over gravel and sand) are of a kind well adapted for purifying a large volume of sewage by filtration. Beddington, however, is worked mainly as a surface irrigation farm. But it is probable that, owing to the porosity of the soil, the surface irrigation at Beddington is supplemented by some filtration through the surface soil.

The sewerage system is partially separate, and all the storm water reaching the sewers is dealt with on the farm. As the volume of this is at times very considerable, it is obvious that the regular working of the farm must be materially interfered with, and this may account for the fact that the effluents varied in quality to a considerable extent.

We are of opinion that 57,100 gallons per acre per 24 hours (9,500 per acre of the total irrigable area) is too large a volume of even a medium-strength sewage to be treated by screening and surface irrigation even over such a porous soil. The volume of sewage dealt with per acre of the "working" daily irrigable area was very large, owing to the "resting" area being five times the "working" area.

The bacteriological results were, generally speaking, less satisfactory than the chemical.

The fact of the Beddington soil and subsoil being fairly comparable in quality with those at Nottingham and Cambridge (compare Section II., Subsection 13), taken together with the filtration results obtained from the "special experiment," leaves no room for doubt that the above-mentioned volume of sewage could be satisfactorily treated if Beddington were laid out as a filtration farm.

Statistical Information.		Bacteriological Results (Average Results per c.c.).
1. Situation of farm	2 miles from Leicester.	*Total number of bacteria* (gelatine at 20° C.):—532,777 (95 per cent. reduction). *Primary standard*, less than 100,000. *Secondary standard*, less than 1,000,000.*
2. Total acreage of farm	1,699 acres.	*Total number of bacteria* (agar at 37° C.):—70,500 (95 per cent. reduction). *Primary standard*, less than 10,000. *Secondary standard*, less than 100,000.
3. Total irrigable area	1,350 acres.	*B. coli*:—At least 1,000, but less than 10,000. *Primary standard*, less than 1,000. *Secondary standard*, less than 10,000§.
4. Average area irrigated at one time	337 acres.	*B. enteritidis sporogenes test*:—At least 10, but less than 100. *Primary standard*, less than 10. *Secondary standard*, less than 100§.
5. Population draining to farm	197,000.	"*Gas*" *test*:— + ·1 c.c.; — ·01 c.c. *Primary standard*, — ·1 c.c. *Secondary standard*, — ·01 c.c.§.
6. Population per acre irrigated	146.	*Neutral-red broth test*:— + ·001 c.c.; — ·0001 c.c. *Primary standard*, — ·001 c.c. *Secondary standard*, — ·0001 c.c.§.
7. Gallons of sewage per head per day	36·8.	None of the effluents were in a fit state to be discharged into a drinking-water stream.
8. Dry weather flow of sewage per 24 hours	7,250,000 gallons.	The effluents failed to pass the primary, but passed successfully the secondary standards for non-drinking-water streams.
9. Gallons of sewage (exclusive of storm water) treated per acre per 24 hours	21,500.	Speaking in general terms, the effluents may be said to have been about 100 times purer than crude sewage.
10. Gallons of sewage treated per acre per 24 hours on the assumption that each acre of the irrigable area is under sewage all the time	5,370.	For further information reference must be made to Section V., Part III. (Bacteriological Report.)
11. Character of the sewage	¾ domestic, ¼ trade refuse.	* It must be definitely understood that these standards are merely provisional and are used for comparative purposes only. § These averages are only approximate.
12. Method of treatment	Screening, settling tanks, surface irrigation and filtration combined.	
13. General character of the soil and subsoil	Stiff clayey soil overlying dense clay.	
14. Separate or combined sewerage system	Partially separate.	
15. The final effluent is discharged into	Anstey Brook (flowing into R. Soar).	
16. Number of years farm in operation before 1900	9 years.	

SEWAGE FARM EFFLUENTS.

Chemical Results.

The analysis of 8 to 13 effluents gave the following figures :—

		Parts per 100,000. Average.
Total nitrogen	(1·84 to 3·64)	2·62
Ammoniacal nitrogen	(0·59 to 2·81)	1·65
Albuminoid ,,	(0·07 to 0·35)	0·20
Total organic ,,	(0·18 to 0·63)	0·45
Nitric + nitrous ,,	(0·0 to 1·73)	0·51
'Oxygen absorbed" from permanganate in 4 hours at 26·7° C. (80° F.)	(1·70 to 4·47)	2·50

Incubator test (smell): 12 out of 13 passed, though one or two of them with difficulty.

Percentage purification on the chance and hourly samples of sewage :—

	Chance. Per cent.	Hourly. Per cent.
(*a*) Calculated on the albuminoid nitrogen	82	85
(*b*) Calculated on the "oxygen absorbed"	80	88

The Leicester final and general effluents were either clear, slightly opalescent, or in one or two cases more or less turbid. They were brown or sometimes yellow in colour, and there was always some flocculent matter present in them, no doubt mainly fragments of weed from the drains, tinged with oxide of iron. When analysed they had a clean smell. The ammoniacal nitrogen was relatively high, constituting about two-thirds of the total nitrogen present, and the nitric nitrogen was—with a few exceptions—very low. Still, the various incubation results showed that the organic matter left in these effluents was of a comparatively non-fermentable character, under laboratory conditions of experiment. The sewage at Leicester is only of moderate strength as regards nitrogen, but it contains much oxidizable matter as measured by the permanganate test.

The Leicester effluents, while not of a high class, are better as regards keeping property than the figures of analysis would lead one to expect; they may be described as medium.

The chemical results from the special experiment at Leicester are of some interest.

For details, see the Chemical Report on the Leicester Farm and the Section upon Soils in Part II.

Remarks.

The sewage ($\frac{3}{4}$ domestic, $\frac{1}{4}$ trade refuse) is only of moderate nitrogenous strength, but contains a considerable amount of oxidizable matter.

For a combined surface irrigation and filtration farm, Leicester was treating a fairly large volume of sewage per acre of the "working" daily irrigable area, but not a large volume per acre of the total irrigable area. As regards the organic matter, it was treating about one-half that of Nottingham (*see* Diagram 5, Section II., Subsection 11).

The soil and subsoil (stiff clayey soil overlying dense clay) are certainly not well suited for purifying a large volume of sewage (compare Section II., Subsection 13).

The sewerage system is partially separate. The farm does not deal with very much storm water.

We think that 21,500 gallons per acre per 24 hours (5,370 gallons per acre of the total irrigable area per 24 hours) is rather too large a volume of a mixed sewage of moderate strength to be treated by screening, settling, and surface irrigation (with some filtration) on soil of the above nature.

(In connection with the foregoing, compare the South Norwood results.)

SOUTH NORWOOD

Statistical Information.		Bacteriological Results (Average Results per c.c.).
1. Situation of farm	Near South Norwood.	*Total number of bacteria* (gelatine at 20° C):—778,322 (98 per cent. reduction). *Primary standard*, less than 100,000. *Secondary standard*, less than 1,000,000.*
2. Total acreage of farm	191 acres.	*Total number of bacteria* (agar at 37° C.):—35,157 (99 per cent. reduction). *Primary standard*, less than 10,000. *Secondary Standard*, less than 100,000.
3. Total irrigable area	152 acres.	*B. coli*:—At least 100, but less than 1,000. *Primary standard*, less than 1,000. *Secondary standard*, less than 10,000.§
4. Average area irrigated at one time	50 acres.	*B. enteritidis sporogenes test*:—At least 10, but less than 100. *Primary standard*, less than 10. *Secondary standard*, less than 100.§
5. Population draining to farm	21,000.	"*Gas*" *test*:— + ·1 c.c.; – ·01 c.c. *Primary standard*, – ·1 c.c. *Secondary standard*, less than – ·01 c.c.§
6. Population per acre irrigated	138.	None of the effluents were in a fit state to be discharged into a drinking-water stream.
7. Gallons of sewage per head per day	28·5.	The effluents, except as regards the B. coli test, failed to pass the primary, but successfully passed the secondary standards for non-drinking-water streams.
8. Dry-weather flow of sewage per 24 hours	600,000 gallons.	Speaking in general terms, the effluents may be said to have been at least 100 times purer than crude sewage.
9. Gallons of sewage (exclusive of storm water) treated per acre per 24 hours	12,000.	For further information reference must be made to Section VI., Part III. (Bacteriological Report.)
10. Gallons of sewage treated per acre per 24 hours on the assumption that each acre of the irrigable area is under sewage all the time	4,000.	* It must be definitely understood that these standards are merely provisional and are used for comparative purposes only. § These averages are only approximate.
11. Character of the sewage	Purely domestic.	
12. Method of treatment	Screening, settling tanks and surface irrigation.	
13. General character of the soil and subsoil	A clay soil resting on London clay.	
14. Separate or combined sewerage system	Partially separate.	
15. The final effluent is discharged into	Chaffinch Beck.	
16. Number of years farm in operation before 1900	36 years.	

SEWAGE FARM EFFLUENTS.

Chemical Results.

For the reasons already stated in the Chemical Report, the analytical data available in respect to the South Norwood effluents are fewer than in the case of the other farms. The following effluents comprise three 2nd field and nine 3rd field, 4th field and general effluents, one of the samples being incubated before analysis. Of the 2nd field effluents two were final effluents, and the third one (No. 29) did not differ materially from the corresponding final effluent, No. 30. It is therefore included here as regards total nitrogen and "oxygen absorbed." Eleven estimations of total nitrogen and of "oxygen absorbed" were made, but only seven of ammoniacal, albuminoid, and nitric nitrogen can be referred to for actual figures.

The following results were obtained :—

	Parts per 100,000. Average.
Total nitrogen (0·55 to 2·83) - -	2·30
Ammoniacal nitrogen (0·02 to 1·55) -	0·87
Albuminoid „ (0·07 to 0·14) -	0·10
Nitric + nitrous „ (0·14 to 0·74 (?))	0·39
"Oxygen absorbed" from permanganate in 4 hours at 26·7° C. (80°F.) (0·97 to 1·73) - - - - -	1·44

Incubator test (smell): 9 out of 12 samples passed.

Percentage purification on the chance and hourly samples of sewage :—

	Chance. Per cent.	Hourly. Per cent.
(*a*) Calculated on the albuminoid nitrogen - - - -	91	85
(*b*) Calculated on the "oxygen absorbed" - - -	87	81

The final effluents varied in appearance, the best having only a slight brown tinge and containing merely a trace of flocculent matter, while there were others which were turbid, with appreciable amounts of matter in suspension. The smell when the samples were analysed was clean. The amount of dissolved oxygen present varied considerably. The nitrate was rather low. The curves for "oxygen absorbed" and total nitrogen follow one another with great regularity.

Taking into account the circumstance that the effluents come from a weak sewage, the results, so far as they go, indicate that rather too much sewage was being treated at the time, a fact which was fully recognised by the local authorities, who were laying down bacterial filters to relieve the pressure on the land.

For details, see the Chemical Report on the South Norwood Farm and the Section upon Soils in Part II.

Remarks.

The sewage (purely domestic) is weak.

South Norwood may be taken as an example of a surface irrigation farm (with a little filtration). It was treating both per acre of the "working" daily irrigable area, and per acre of the total irrigable area, a small volume of sewage and a very small quantity of organic matter in the aggregate (*see* Diagram 5, Section II., Subsection 11).

The soil (a partially modified clay soil resting on London clay) is not very well adapted for purifying even a moderate volume of sewage (compare Section II., Subsection 13).

The sewerage system is partially separate. All the storm water reaching the sewers is dealt with on the farm.

We consider that even 12,000 gallons per acre per 24 hours (4,000 gallons per acre of the total irrigable area per 24 hours) is possibly too large a volume of even a weak sewage to be treated by screening, settling, and surface irrigation (with some little filtration) on surface soil of the above nature. Nevertheless, it should not be forgotten here that the difficulty of treating the storm water at South Norwood must be relatively great.

In comparing Leicester and South Norwood, two typical clay farms, it should further be remembered that although the Leicester Farm was treating a much larger volume of sewage per acre and a larger amount of organic matter in the aggregate, it had to deal with much less storm water, and in all probability benefited to a greater extent by filtration, which, however, must in any case have been comparatively small.

Statistical Information.		Bacteriological Results.
1. Situation of farm	Stoke Bardolph, 5 miles from Nottingham.	The effluents stand in a class by themselves. Some of them were so pure bacteriologically as to resemble drinking water. For the reasons given in Part III. (Bacteriological Report), the effluents could not be discharged into drinking-water streams without some element of risk. They easily "passed" the primary standards for non-drinking-water streams. For detailed information, Section VII. of the Bacteriological Report must be consulted.
2. Total acreage of farm	907 acres (1900).	
3. Total irrigable area	651 acres (1900).	
4. Average area irrigated at one time	300 acres.	
5. Population draining to farm	258,584.	
6. Population per acre irrigated	397.	
7. Gallons of sewage per head per day	27 gallons.	
8. Dry weather flow of sewage per 24 hours	7,000,000 gallons.	
9. Gallons of sewage (exclusive of storm water) treated per acre per 24 hours	23,300.	
10. Gallons of sewage treated per acre per 24 hours on the assumption that each acre of the irrigable area is under sewage all the time	10,750.	
11. Character of the sewage	$\frac{4}{7}$th domestic, $\frac{3}{7}$th trade refuse.	
12. Method of treatment	Screening (partial) and land filtration.	
13. General character of the soil and subsoil	Light sandy loam and gravel overlying gravel and sand.	
14. Separate or combined sewerage system	Combined.	
15. The final effluent is discharged into	River Trent.	
16. Number of years farm in operation before 1900	10½ years.	

SEWAGE FARM EFFLUENTS.

Chemical Results.

13 Samples of effluent (omitting No. 11, an effluent from a field which had been *purposely* over-sewaged) gave the following figures :—

		Parts per 100,000. Average.
Total nitrogen	(1·41 to 3·45)	2·27
Ammoniacal nitrogen	(0·01 to 0·29)	0·13
Albuminoid ,,	(0·01 to 0·10)	0·03
Nitric + nitrous ,,	(1·25 to 3·29)	2·06
Do. in 4 further samples	(1·24 to 1·71)	1·44
"Oxygen absorbed" from permanganate in 4 hours at 26·7° C. (80° F.)	(0·05 to 0·37)	0·19

Incubator test (smell) : All 17 samples passed.

Percentage purification on both the chance and hourly samples of sewage :—

	Chance. Per cent.	Hourly. Per cent.
(*a*) Calculated on the albuminoid nitrogen	99	98
(*b*) Calculated on the "oxygen absorbed"	99	99

The Nottingham Farm effluents were of quite exceptional quality, the best of them approaching in fact, chemically, to drinking waters. The earlier samples were uniformly clear, colourless, without sediment and without smell ; the last four samples examined (partially), while also clear, colourless and without smell, contained quite appreciable amounts of red-brown flocculent matter from the drain pipes. These four were less well aërated than the others, and evidently not of such a high class, though still very good. It is unnecessary to enter into further details here, full particulars being given in the Chemical Report on the Nottingham Farm and in the Section upon Soils in Part II.

Remarks.

The sewage ($\frac{4}{7}$th domestic, $\frac{3}{7}$th trade refuse) is strong.

For a filtration farm, Nottingham was not treating a large volume of sewage, either per acre of the "working" daily irrigable area, or per acre of the total irrigable area, more especially if the nature and effective internal purifying surface of the soil and subsoil are taken into consideration. But it was actually treating a large quantity of organic matter (*see* Diagram 5, Section II, Subsection 11).

The sewerage system is combined, but the farm deals with very little of the storm water.

There can be no doubt that 23,300 gallons per acre per 24 hours (10,750 gallons per acre of the total irrigable area per 24 hours) is not too large a volume of even a strong sewage to be treated by screening (partial) and filtration through about 6 feet of soil and subsoil (sandy loam overlying gravel and sand) of the nature of that found at Nottingham.

It is pleasant to be able to call attention to the fact of a sewage farm working well within its limits of purifying power, and as a result yielding effluents of a highly satisfactory character.

Statistical Information.		Bacteriological Results (Average Results per c.c.).
1. Situation of farm	New Bilton, 1 mile from Rugby.	*Total number of bacteria* (gelatine at 20° C.):—637,133 (97 per cent. reduction). *Primary standard*, less than 100,000. *Secondary standard*, less than 1,000,000.*
2. Total acreage of farm	40 acres.	*Total number of bacteria* (agar at 37° C.):—81,526 (97 per cent. reduction). *Primary standard*, less than 10,000. *Secondary standard*, less than 100,000.
3. Total irrigable area	35 acres.	*B. coli*:—At least 1,000, but less than 10,000. *Primary standard*, less than 1,000. *Secondary standard*, less than 10,000.§
4. Average area irrigated at one time	7 acres.	*B. enteritidis sporogenes test*:—At least 10, but less than 100. *Primary standard*, less than 10. *Secondary standard*, less than 100.§
5. Population draining to farm	6,000.	"*Gas*" *test*:— + ·1 c.c.; — ·01 c.c. *Primary standard*, — ·1 c.c. *Secondary standard*, — ·01 c.c.§
6. Population per acre irrigated	171.	*Neutral-red broth test*:— + ·01 c.c.; — ·001 c.c. *Primary standard*, — ·001 c.c. *Secondary standard*, — ·0001 c.c.§
7. Gallons of sewage per head per day	50.	None of the effluents were in a fit state to be discharged into a drinking-water stream.
8. Dry weather flow of sewage per 24 hours	300,000 gallons.	The effluents failed to pass the primary, but passed successfully the secondary standards for non-drinking-water streams.
9. Gallons of sewage (exclusive of storm water) treated per acre per 24 hours	42,800.	Speaking in general terms, the effluents may be said to have been about 100 times purer than crude sewage.
10. Gallons of sewage treated per acre per 24 hours on the assumption that each acre of the irrigable area is under sewage all the time	8,500.	For further information reference must be made to Section VIII., Part III. (Bacteriological Report.)
11. Character of the sewage	Mainly domestic.	
12. Method of treatment	Screening, chemical precipitation, settling tanks, and surface irrigation and filtration combined.	
13. General character of the soil and subsoil	Heavy loam overlying stiff clay.	
14. Separate or combined sewerage system	Partially separate.	
15. The final effluent is discharged into	River Avon.	
16. Number of years farm in operation before 1900	33 years.	

* It must be definitely understood that these standards are merely provisional and are used for comparative purposes only.

§ These averages are only approximate.

SEWAGE FARM EFFLUENTS.

Chemical Results.

The examination of 16 to 19 effluents gave the following figures :—

		Parts per 100,000. Average.
Total nitrogen	(1·39 to 2·96)	2·31
Ammoniacal nitrogen	(0·97 to 2·81)	1·62
Albuminoid ,,	(0·08 to 0·39)	0·18
Nitric + nitrous ,,	(0·0 to 1·59)	0·52
"Oxygen absorbed" from permanganate in 4 hours at 26·7° C. (80° F.)	(0·72 to 2·16)	1·41

Incubator test (smell): 15 out of 20 samples passed.

Percentage purification on the chance and hourly samples of sewage :—

	Chance. Per cent.	Hourly. Per cent.
(*a*) Calculated on the albuminoid nitrogen	88	89
(*b*) Calculated on the "oxygen absorbed"	91	92

Most of the Rugby 2nd Field effluents had a faint yellow tinge, due to organic matter; they contained but little flocculent suspended solids. The smell, when the effluents came to be analysed, was clean. The dissolved oxygen was practically *nil* in most of the summer samples, and moderate in amount in those drawn in spring; but in the latter it did not appear to be taken up rapidly between the times of drawing and of analysis—a good sign. The nitrate was, on the whole, deficient. The effluents were fair in spring, but not good in summer, when the concentration was rather greater (we had, however, only six summer samples). The Rugby sewage is a strong one, hence the above purification is good relatively, but it does not go quite far enough.

For details, see the Chemical Report on the Rugby Farm and the Section upon Soils in Part II.

Remarks.

The sewage (mainly domestic) is distinctly strong, although not quite so strong as the sewage at Aldershot Camp and Nottingham.

For a combined surface irrigation and filtration farm Rugby was treating a large volume of sewage, more especially per acre of the "working" daily irrigable area, but also per acre of the total irrigable area. The sewage being strong, the farm was therefore treating in the aggregate a large quantity of organic matter, namely, about one-half the total amount which Cambridge treats (*Cf.* Diagram 5, Section II., Subsection 11).

The soil and subsoil (heavy loam overlying stiff clay with gravel "pockets") is certainly not of an ideal kind for purifying a large volume of sewage (compare Section II, Subsection 13). It is advisable, however, to call attention here to the method of treatment followed at Rugby, namely, the mixing of one volume of effluent from a larger plot of ground with an equal volume of sewage, and the passing of that mixture over a second smaller plot.

The sewerage system is partially separate, but a large proportion of the storm water is treated on the farm.

We consider that 42,800 gallons per acre per 24 hours (8,500 gallons per acre of the total irrigable area per 24 hours) is too large a volume of a strong sewage to be treated by screening, settling, and surface irrigation (with some filtration) on soil of the above nature.

Remarks, as regards the foregoing Subsection.

It was not to be anticipated either that the chemical and bacteriological results should always show a direct parallelism, or that the inferences to be deduced from the separate results should in all cases be in close agreement. Nevertheless, the tentative opinion previously expressed to the Commission, namely, that the chemical and bacteriological aspects of the problem of sewage purification are not mutually antagonistic, but rather related to and in sympathy with each other, does not appear to have been premature, or to have been disproved by the results of our independent analyses.

Looking at the subject from separate points of view, we have come to the same conclusion, namely, that in the present state of knowledge the association of biology with chemistry is to be recommended in connection with the discharge of effluents into any streams, whether these be drinking or non-drinking water streams. In the former case (*i.e.*, discharge into a drinking water stream), we consider the bacteriological results of more importance than the chemical; but in the latter (discharge into a non-drinking water stream), the converse holds good, *i.e.*, the chemical results are of first importance.

In the foregoing statement we have dealt with the subject chiefly from the point of view of non-drinking water streams. It follows, then, that in our conclusions, whenever any divergencies between the chemical and bacteriological results have occurred, our remarks have been largely governed by chemical considerations. Nevertheless, generally speaking, the chemical and bacteriological results have shown a fair degree of correspondence.

2. *Special comparison.* [*Compound Chemical and Biological curves* (*for comparative purposes only.*)]

Diagram 10 illustrates, as regards the effluents from the eight principal sewage farms which have been under observation, the following points :—

Diagram 10.

Diagram A - - - Diagram B - - - Diagram C - - -	Show, as regards total number of bacteria (gelatine at 20° C., and agar at 37° C.); number of B. coli or coli-like microbes ; B. enteritidis sporogenes ; "gas"; and neutral red broth tests, the results of the bacteriological examination of the effluents from the eight sewage farms kept under detailed observation.

Diagram D shows a compound biological curve of doubtful value unless for comparative purposes.

Diagram E is a compound chemical curve (*approximate*) which is given for purposes of comparison with the compound biological curve. It may be stated that diagrams D and E were constructed quite independently of one another.

Since the diagrams include all kinds of effluents (*i.e.*, normal filtration effluents, filtration effluents from new — *i.e.*, unmatured — land, surface irrigation effluents from treatment over one, two, and three fields, effluents from special experiments, etc.), they are *not* to be taken as representing in any way the purification effected at the different farms. *They are merely given here for the above-mentioned comparisons.*

Diagram 11.

It may perhaps be easier to see similarities and dissimilarities in the compound chemical and bacteriological curves, if these are arranged according to the class of effluent, and not according to the consecutive numbers. We, therefore, append the curves made out in this way also, "*blanks*" being omitted (*see* Diagram 11, F-G). Further, the chemical results (F) are arranged in the inverse order of their purity for each class of effluent, the bacteriological results (G) in the *corresponding* samples being given.

Following the diagrams are printed columns showing the nature of each individual effluent.

NOTE.—It may perhaps be well to call attention to the fact that the curves on the bacteriological diagrams are not true curves.

Remarks, as regards Diagrams 10 *and* 11.

Diagrams 10 and 11 show, as regards the effluents from the eight sewage farms kept under detailed observation, the following points :—

Diagram 10.

I. Diagrams A, B, and C show that a broad parallelism exists between the results obtained by the use of the following tests:—(1) Total number of bacteria (gelatine at 20° C., and agar at 37° C.); (2) number of B. coli; (3) B. enteritidis sporogenes test; (4) "gas" test; and (5) neutral red broth test. The agreement, however, is not so close as to make it desirable to draw conclusions from the use of any single test. At least two tests (preferably the B. coli and B. enteritidis sporogenes tests) should be applied to every sample.

II. In Diagrams D and E the compound biological and chemical curves respectively are brought into comparison. Both curves are approximate only, and of doubtful value unless for comparative purposes.

Diagram 11.

III, In Diagrams F and G the chemical and bacteriological results are again compared, but in the modified way previously explained.

Generally speaking the agreement is satisfactory, but the individual discrepancies are too wide and frequent to allow in all cases, and with regard to isolated samples, of (*a*) either the bacteriological results being taken as a safe indication of the amount and nature of the organic matter present; (*b*) or the chemical results being considered a reliable measure of the biological qualities of an effluent.

Diagram 10.

Diagram showing as regards total number of bacteria (Gelatine at 20°C. and Agar at 37°C.) number of B. coli; and B. Enteritidis sporogenes; "gas" & neutral red broth tests the results of the bacteriological examination of effluents of all sorts from the eight sewage farms kept under detailed observation; together with a comparison between the chemical & bacteriological results by means of "Compound Curves" which are intended for comparative purposes only.

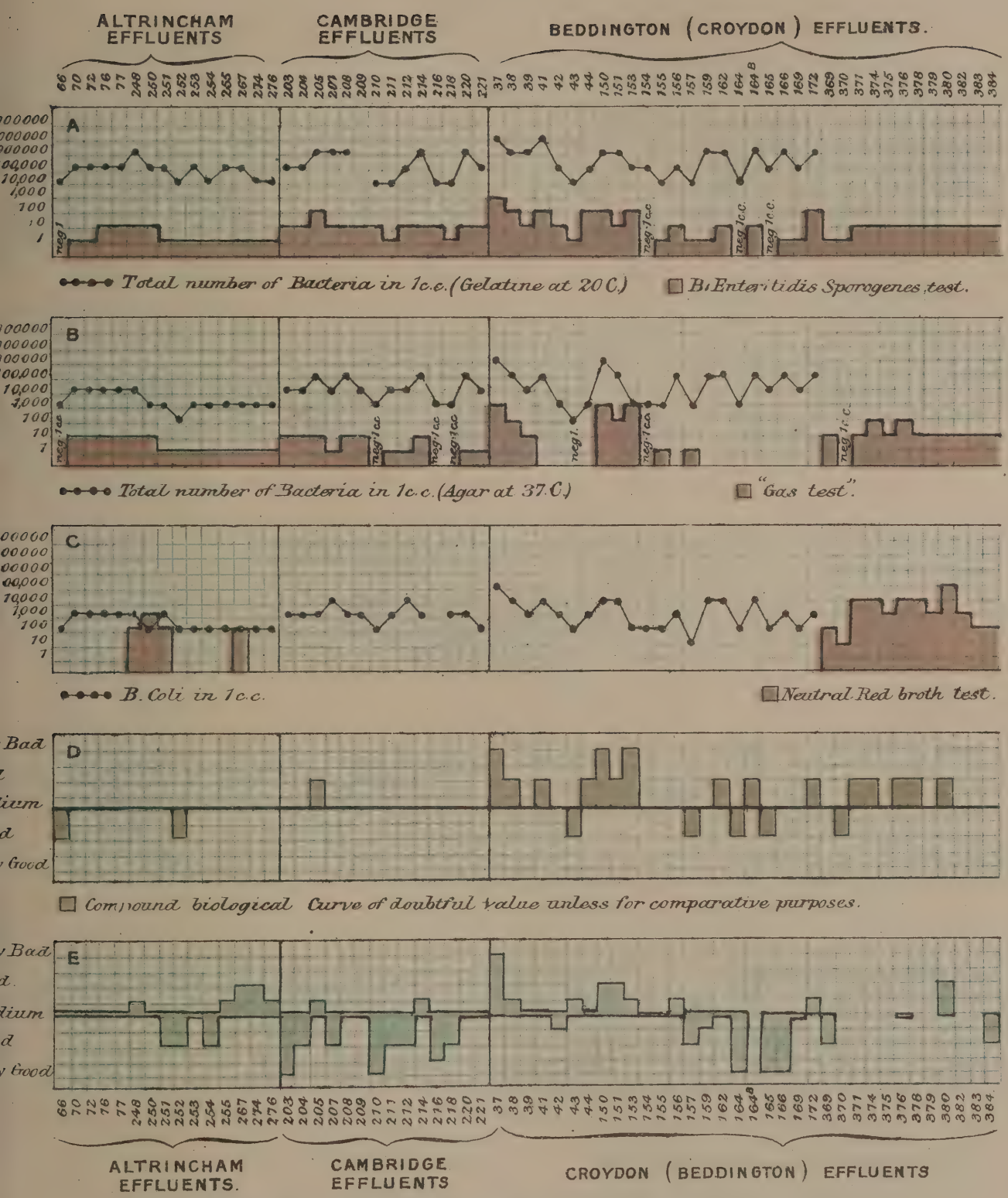
ALDERSHOT CAMP EFFLUENTS.

ALDERSHOT CAMP EFFLUENTS.

☐ Compound Chemical curve (very approximate), which is given for comparison with the Compound Biological curve. Where no analysis of a sample was made there is a break in the Curve. The Curves were, in the first instance, made out for the Bacteriological samples & do not therefore comprise all the chemical results, not all of the samples having been examined both chemically & bacteriologically.

3311.1-03

Diagram continued. (Diag. 10)(a)



Compound Chemical Curve (very approximate) which is given for comparison with the Compound Biological Curve.

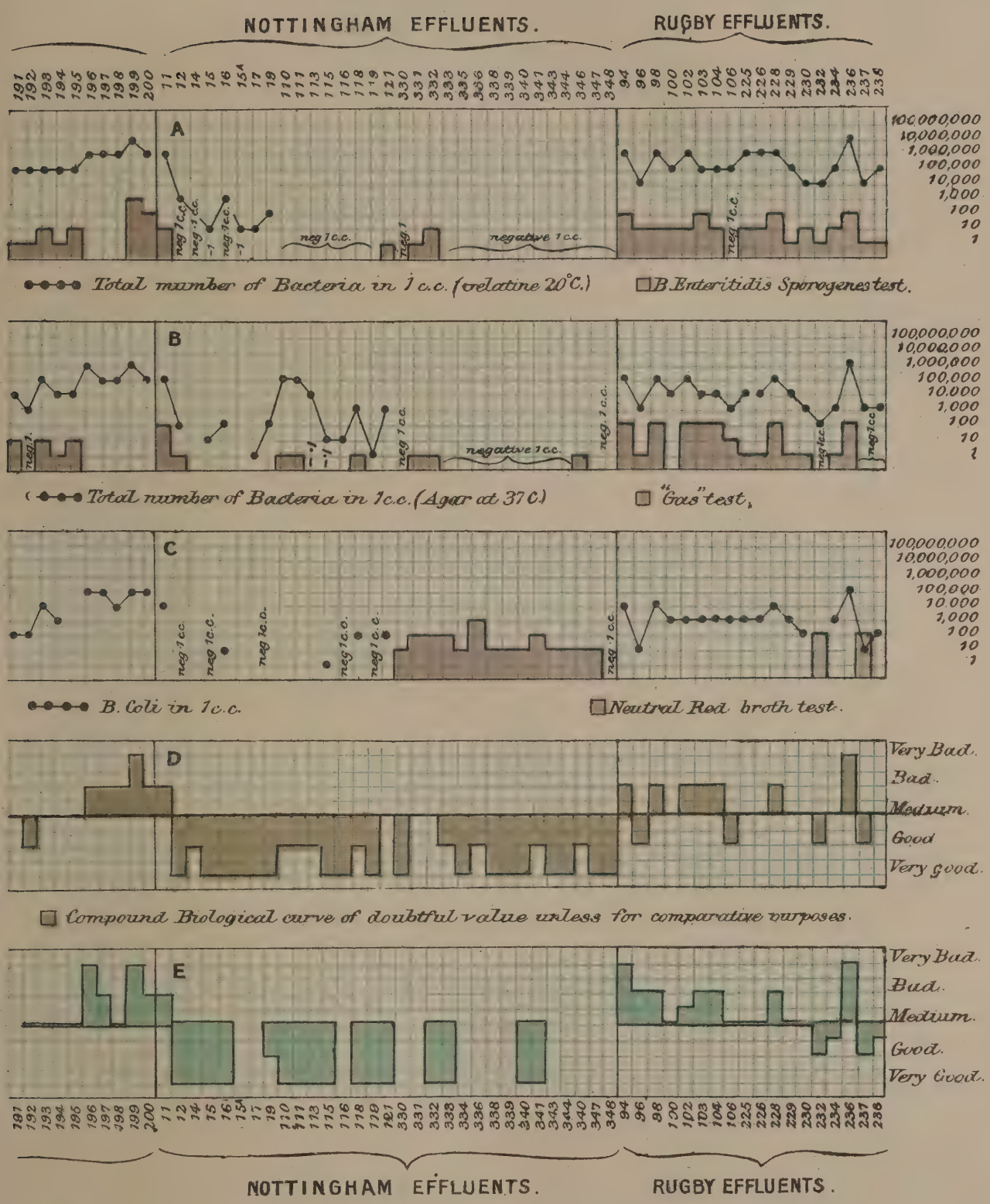
3311 1 02.

E. Weller & Grahams, Ltd Litho. London.

Diagram continued. (Diag. 10).[b]

Compound Chemical curve (very approximate), which is given for comparison with the Compound Biological curve. Where no analysis of a sample was made there is a break in the curve. The curves were, in the first instance, made out for the bacteriological samples & do not therefore comprise all the chemical results, not all of the samples having been examined both chemically & bacteriologically.

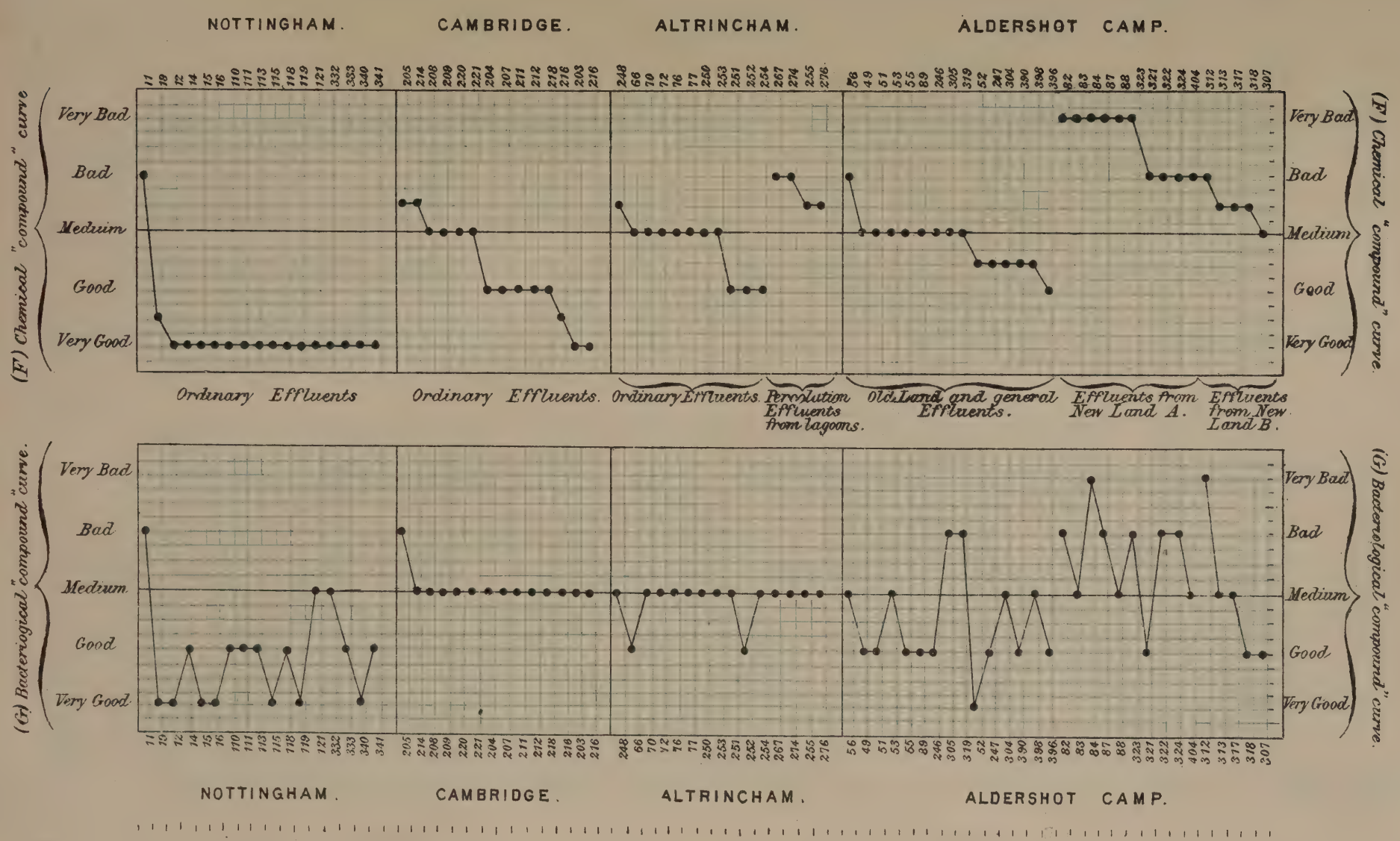
Diagram continued (Diag. 10). (C)



11.1.02.

Weller & Graham, Ltd Litho. London.

Diagram showing a comparison between (F) the chemical "compound" curve and (G) the bacteriological "compound" curve.

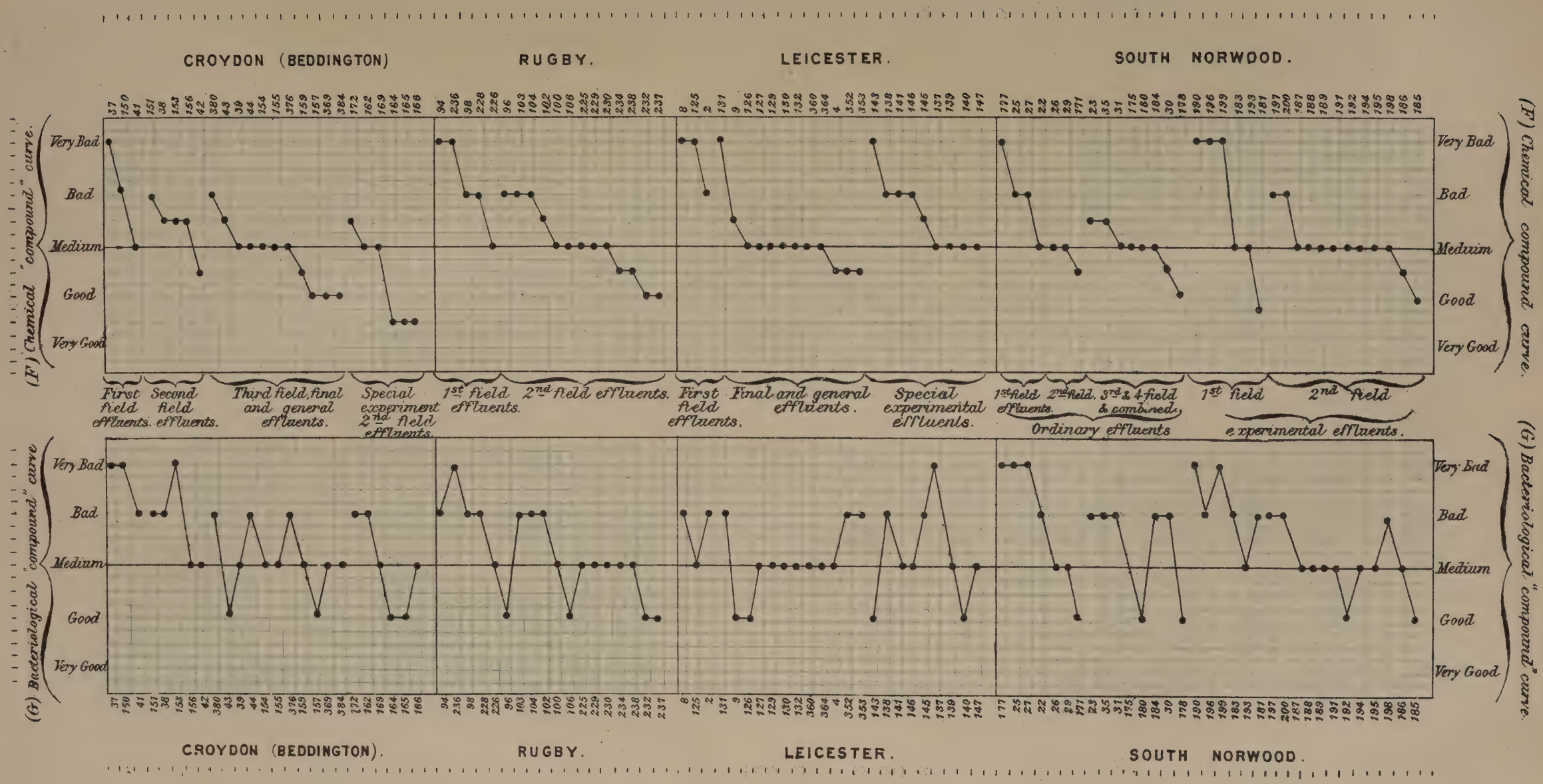


These curves are only to be taken as approximate. They were made out quite independently, with the object of seeing how far the general Chemical and Bacteriological results showed a parallelism.
The samples are arranged according to the class of effluent (e.g. 1st field, 2nd field, 3rd field, New Land, Old Land, Experimental effluents).
Further the chemical results are arranged in sequence, the worst samples from each class coming first, and the best samples last. The bacteriological results in the corresponding samples are given.

3311 2 03.

Weller & Graham Ltd Litho. London.

Diagram Continued. Diag. 11(a).



Weller & Graham. Ltd Litho. Lond

3. *Comparison between the Chemical and Biological results as regards albuminoid nitrogen and total number of bacteria.*

Diagram 12 shows, as regards albuminoid nitrogen and total number of bacteria (agar at 37° C.), a comparison between the chemical and biological qualities of effluents from the eight principal farms which have been under observation.

The albuminoid nitrogen may be taken as representing, roughly, the organic pabulum on which the bacteria feed.

Since the diagrams include all kinds of effluents (*i.e.*, normal filtration effluents, filtration effluents from new—*i.e.*, unmatured—land, surface irrigation effluents from treatment over one, two, and three fields, effluents from special experiments, etc.), they are *not* to be taken as representing in any way the purification effected at the different farms. *They are merely given here for the above-mentioned comparison.*

Following the diagrams are printed columns showing the nature of each individual effluent.

Remarks, as regards diagram 12.

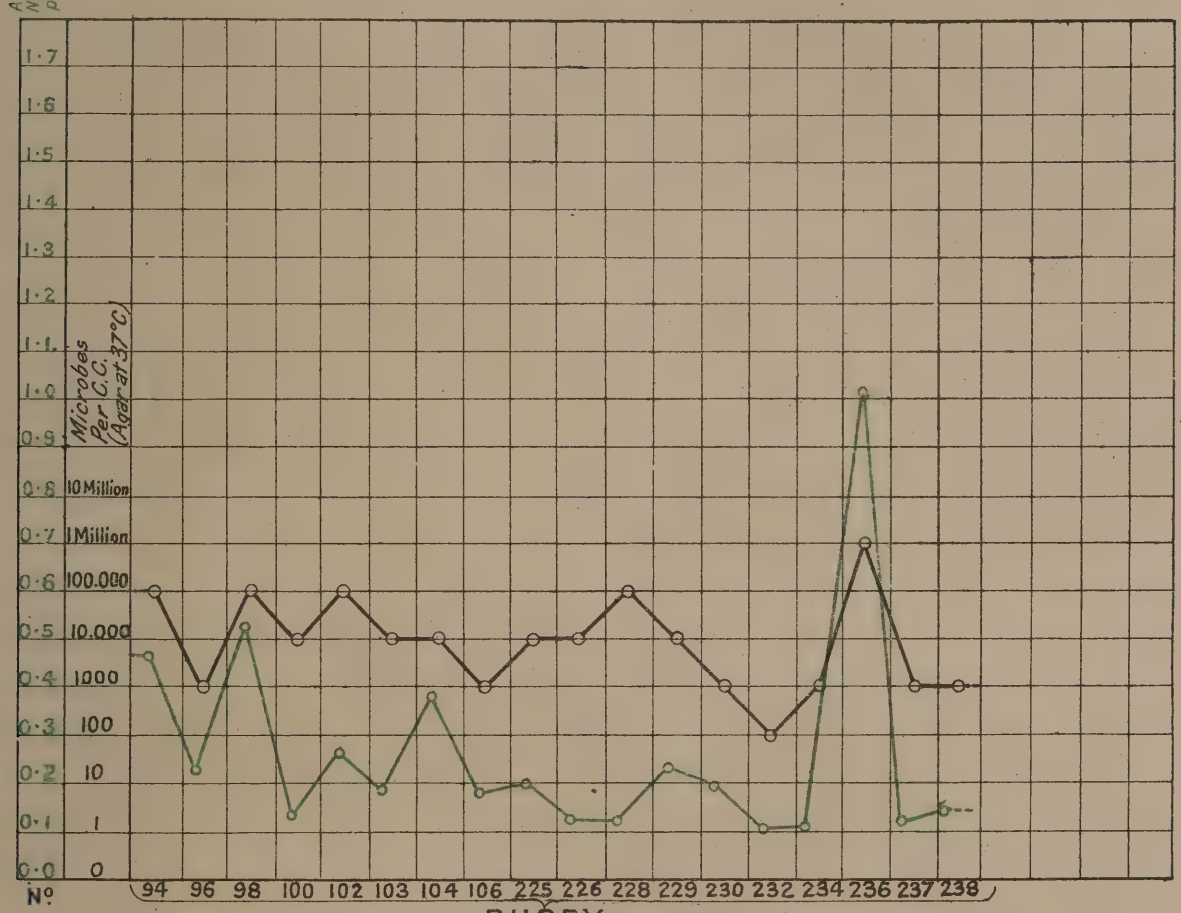
Diagram 12 shows that there is a broad parallelism between the curves for (*a*) the albuminoid nitrogen and (*b*) the total number of bacteria (agar at 37° C.). Nevertheless, neither (*a*) the chemical nor (*b*) the bacteriological analysis of *isolated samples* of effluent could be taken singly as necessarily affording a reliable indication of either the total number of bacteria present, or the amount of albuminoid nitrogen, respectively.

As already stated on page 96, we have come to the conclusion that in the case of drinking water streams chief reliance should be placed on the bacteriological results; that as regards non-drinking water streams the converse holds true (*i.e.*. the chemical results are of primary importance); but that in nearly all cases there is an advantage in the association of both chemistry and biology in the investigation of the complex problems coming under the head of sewage purification.

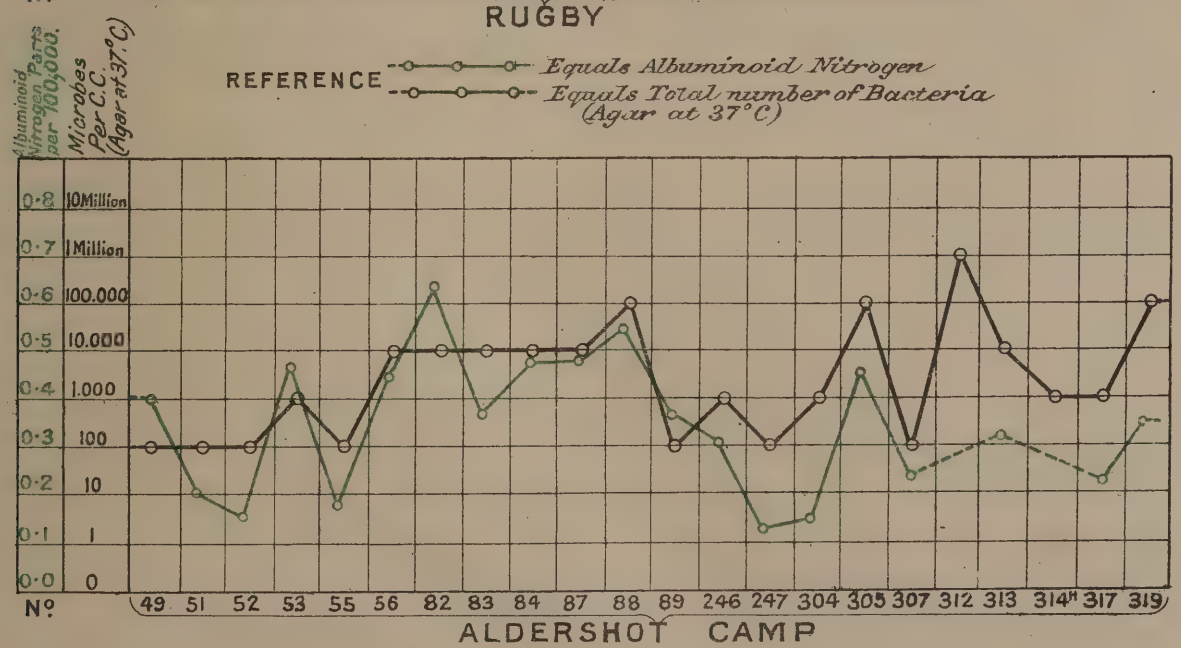
Diagram 12.

DIAGRAM showing, as regards Albuminoid Nitrogen & Total number of Bacteria (Agar at 37°C), a comparison between the chemical & biological qualities of Effluents from Rugby & Aldershot Camp Sewage Farms.

The Albuminoid Nitrogen may be taken as representing roughly the Organic Pabulum on which the Bacteria feed



REFERENCE -o—o—o- Equals Albuminoid Nitrogen
-o—o—o- Equals Total number of Bacteria (Agar at 37°C)



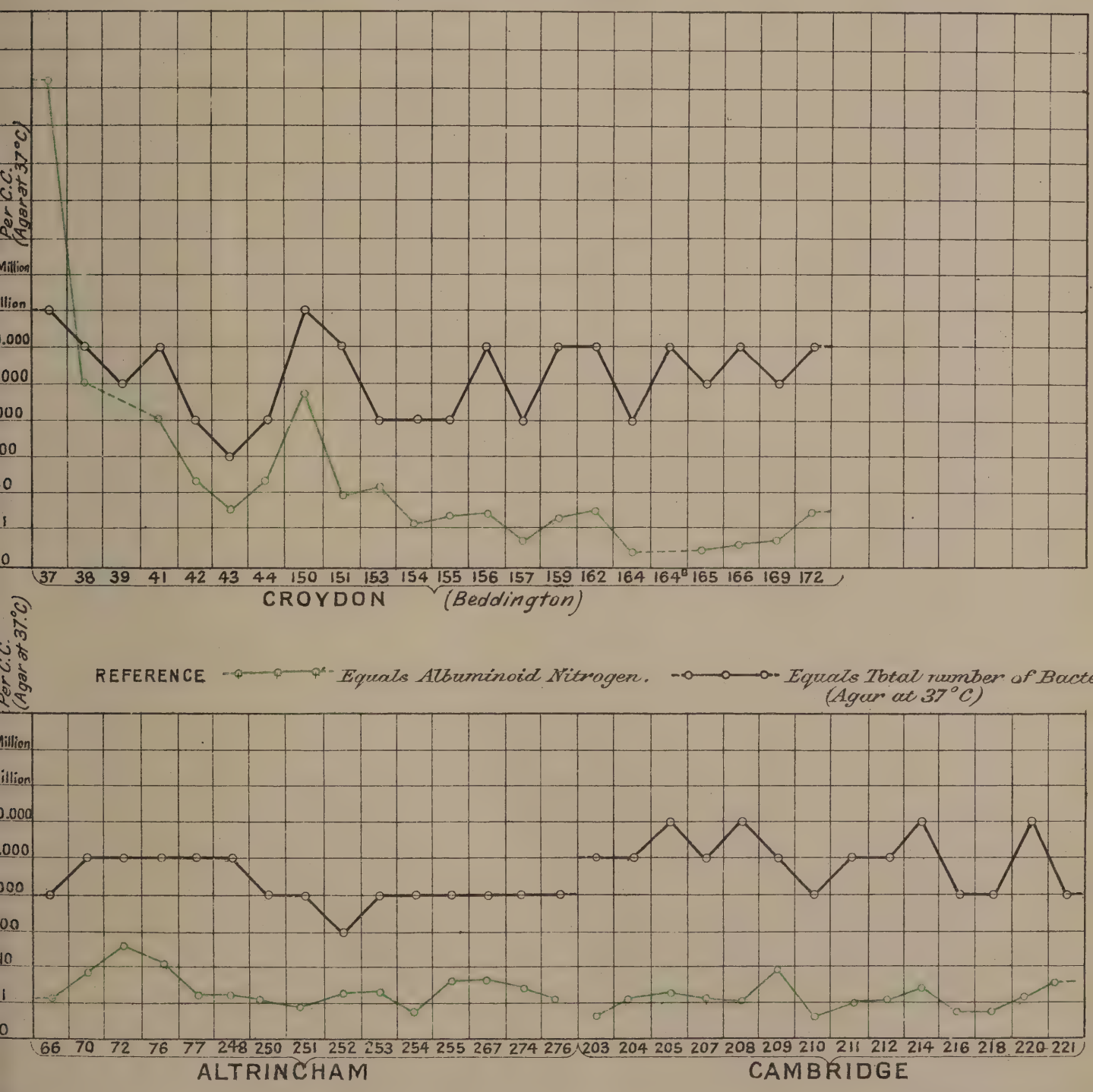
3332.1.03.

Weller & Graham, Ltd. Litho. London.

Diagram 12. continued (a).

DIAGRAM *showing, as regards Albuminoid Nitrogen & Total number of Bacteria (Agar at 37°C), a comparison between the chemical & biological qualities of Effluents from Croydon (Beddington), Altrincham & Cambridge Sewage Farms.*

The Albuminoid Nitrogen may be taken as representing roughly the Organic Pabulum on which the Bacteria feed.



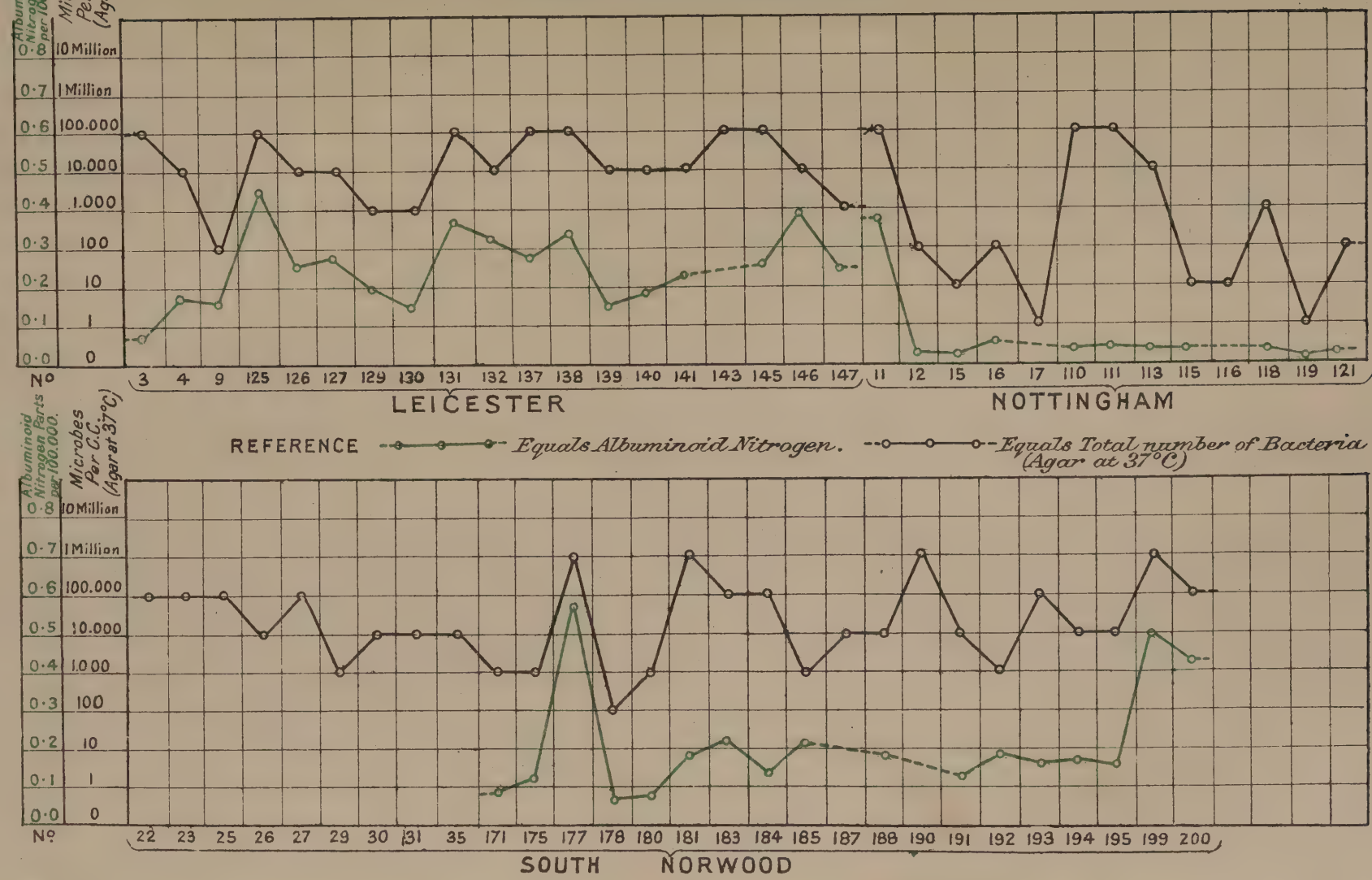
03.

Weller & Graham Ld Litho. London.

Diagram 12 continued. (b).

DIAGRAM *showing, as regards Albuminoid Nitrogen & Total number of Bacteria (Agar at 37°C), a comparison between the chemical & biological qualities of Effluents from Leicester, Nottingham, & South Norwood Sewage Farms.*

The Albuminoid Nitrogen may be taken as representing roughly the Organic Pabulum on which the Bacteria feed.



3332.1.03.

Weller & Graham Ltd Litho. London

4.—*Nature of each individual effluent given in the preceding diagrams.*

Leicester Effluents.

	No. 2	Over one field.
	,, 3	Over three fields.
	,, 4	Over two fields.
	,, 8	Over one field.
	,, 9	Over two fields.
	,, 125	Over one field.
	,, 126	Over two fields.
	,, 127	Over two fields.
	,, 129	Over two fields.
	,, 130	Over two fields.
	,, 131	Over two fields.
	,, 132	General effluent.
Special experiment.	,, 137	Over two fields.
	,, 138	Over two fields.
	,, 139	Over two fields.
	,, 140	Over two fields.
	,, 141	Over two fields.
	,, 143	Over two fields.
	,, 145	Over two fields.
	,, 146	Over two fields.
	,, 147	Over two fields.
	,, 350	Surface effluent.
	,, 351	From arable field.
	,, 352	Over three fields.
	,, 353	General effluent.
	,, 354	General effluent.
	,, 356	General effluent.
	,, 358	First field effluent.
	,, 359	Second field effluent.
	,, 360	Over three fields.
	,, 362	First field effluent.
	,, 363	Final effluent.
	,, 364	General effluent.
	,, 366	First field effluent.
	,, 367	Final effluent.
	,, 368	General effluent.

Nottingham Effluents.

No. 11	Filtration effluent from field which had been heavily over-sewaged intentionally.
,, 12	Final and general filtration effluents.
,, 15	
,, 16	
,, 17	
,, 110	
,, 111	
,, 113	
,, 115	
,, 116	
,, 118	
,, 119	
,, 121	

Additional Nottingham Effluents.

No. 14	Final effluent.
,, 15A	Final effluent.
,, 19	Final effluent.
,, 330	Final effluent.
,, 331	Final effluent.
,, 332	General effluent.
,, 333	General effluent.
,, 335	Final effluent
,, 336	Final effluent.
,, 338	Final effluent.
,, 339	Final effluent.
,, 340	General effluent.
,, 341	General effluent.
,, 343	Final effluent.
,, 344	Final effluent.
,, 346	General effluent.
,, 347	Final effluent.
,, 348	Final effluent.

South Norwood Effluents.

	No. 22	Over one field.
	,, 23	Over three fields.
	,, 25	Over one field.
	,, 26	Over two fields
	,, 27	Over one field.
	,, 29	Over two fields.
	,, 30	Over three fields.
	,, 31	General effluent
	,, 35	General effluent.
	,, 171	Over two fields.
	,, 175	Over four fields.
	,, 177	Over one field.
	,, 178	Over three fields.
	,, 180	Over three fields.
Special experiment.	,, 181	Over one field.
	,, 183	Over one field.
	,, 184	General effluent.
	,, 185	Over two fields.
	,, 186	Over two fields.
	,, 187	Over two fields.
	,, 188	Over two fields.
	,, 189	Over two fields.
	,, 190	Over one field.
	,, 191	Over two fields.
	,, 192	Over two fields.
	,, 193	Over one field.
	,, 194	Over two fields.
	,, 195	Over two fields
	,, 196	Over one field.
	,, 197	Over two fields.
	,, 198	Over two fields.
	,, 199	Over one field.
	,, 200	Over two fields.

Croydon (Beddington) Effluents

	No. 37	Over one field.
	,, 38	Over two fields.
	,, 39	Over three fields.
	,, 41	Over one field.
	,, 42	Over two fields.
	,, 43	Over three fields.
	,, 44	General effluent.
	,, 150	Over one field.
	,, 151	Over two fields.
	,, 153	Over two fields.
	,, 154	Over three fields.
	,, 155	Over three fields
	,, 156	Over two fields
	,, 157	Over three fields.
	,, 159	Over three fields.
Special experiment.	,, 162	(Filtration effluent) over one field.
	,, 164	(Filtration) over two fields.
	,, 164B	(Filtration) over one field
	,, 165	(Filtration) over two fields.
	,, 166	(Filtration) over two fields.
	,, 169	(Filtration and irrigation) over two fields.
	,, 172	(Filtration and irrigation) over two fields.
	,, 369	General effluent.
	,, 370	Final effluent.
	,, 371	Final effluent.
	,, 374	Final effluent.
	,, 375	Final effluent.
	,, 376	General effluent.
	,, 378	Final effluent.
	,, 379	Final effluent.
	,, 380	General effluent.
	,, 382	Final effluent.
	,, 383	Final effluent
	,, 384	General effluent.
	,, 386	General effluent
	,, 387	Final effluent
	,, 388	Final effluent

Aldershot Camp Filtration Effluents.

No.	49	Old land.
,,	51	Old land.
,,	52	Old land.
,,	53	Old land.
,,	55	Old land.
,,	56	Old land.
,,	82	New land (A).
,,	83	New land (A).
,,	84	New land (A).
,,	87	New land (A).
,,	88	New land (A).
,,	89	Old land.
,,	246	Old land.
,,	247	Old land.
,,	304	Old land.
,,	305	Old land.
,,	307	New land (B).
,,	312	New land (B).
,,	313	New land (B).
,,	314A	Effluent, new land.
,,	314B	Effluent, old land.
,,	314C	Effluent, old land.
,,	314D	Effluent, new land (B).
,,	314E	Effluent, old land.
,,	314F	Effluent, old land.
,,	314H	Effluent, new land.
,,	317	New land (B).
,,	317A	General effluent, old land.
,,	318	New land (B).
,,	318A	General effluent, old land.
,,	318C	General effluent, old land.
,,	318D	Effluent, new land (B).
,,	318E	General effluent, old land.
,,	318F	Effluent, new land (B).
,,	319	Old land.
,,	319A	General effluent, old land.
,,	319C	Effluent, old land.
,,	320A	General effluent, old land.
,,	321	New land (A).
,,	322A	General effluent, old land.
,,	322	New land (A).
,,	322B	General effluent, old land.
,,	322C	Effluent, old land.
,,	323	New land (A).
,,	323B	General effluent, old land.
,,	324	New land (A).
,,	324A	General effluent, old land.
,,	395	Final effluent
,,	392	Final effluent.
,,	394	Final effluent.
,,	400	Final effluent.
,,	391	Final effluent.
,,	396	Old land.
,,	398	Old land.
,,	399	Final effluent.
,,	404	New land (A).
,,	403	Final effluent.
No.	407	General effluent.
,,	408	Final effluent.
,,	390	Old land.
,,	402	General effluent.
,,	406	Final effluent.

Altrincham Effluents

No.	66	Ordinary filtration effluents.
,,	70	
,,	72	
,,	76	
,,	77	
,,	248	
,,	250	
,,	251	
,,	252	
,,	253	
,,	254	
,,	255	Percolation effluents from lagoons.
,,	267	
,,	274	
,,	276	

Rugby Effluents.

No.	94	Over one field.
,,	96	Over two fields.
,,	98	Over one field.
,,	100	Over two fields.
,,	102	Over two fields.
,,	103	Over two fields.
,,	104	Over two fields.
,,	106	Over two fields.
,,	225	Over two fields.
,,	226	Over one field.
,,	228	Over one field.
,,	229	Over two fields.
,,	230	Over two fields.
,,	232	Over two fields.
,,	234	Over two fields.
,,	236	Over one field.
,,	237	Over two fields.
,,	238	Over two fields.

Cambridge Effluents.

No.	203	Final and general filtration effluents.
,,	204	
,,	205	
,,	207	
,,	208	
,,	209	
,,	210	
,,	211	
,,	212	
,,	214	
,,	216	
,,	218	
,,	220	
,,	221	

SECTION VIII.

ENGINEERING AND PRACTICAL CONCLUSIONS.

This heading is retained for the sake of completeness, although the subject matter has been (1) either sufficiently considered already under Sections II. and IV., or (2) will be covered by the General Conclusions given in Section IX., the notes in Appendix A, and, so far as detailed information is concerned, in Part IV. (Engineering and Practical Report).

SECTION IX.

GENERAL CONCLUSIONS.

The effluents from land processes of sewage treatment are not, from the bacteriological point of view, in a proper condition for discharge into drinking water streams (*see* Part III., Bacteriological Report).

Can land effluents be discharged into drinking water streams ?

The effluents from land possess a bacterial flora characteristic of sewage, and the microbes characteristic of soil (in the sense of being peculiarly abundant in soil) are *relatively* absent from land effluents (*see* Part III., Bacteriological Report).

Is the bacterial flora of land effluents characteristic of sewage or of soil ?

As a result of its treatment on land, and judged by the bacteriological tests employed in this investigation, sewage does not seemingly become modified in its biological characters to any material extent (*see* Part III., Conclusions). The bacteria, however, were reduced in number to a marked extent (*see* Part III., Bacteriological Report).

Is the bacterial flora of sewage intrinsically modified by land treatment ?

The few samples of subsoil water collected in the neighbourhood of some of the sewage farms were usually found to be pure, both chemically and bacteriologically, but this, of course, must not be regarded as proving that wells sunk in such situations are safe for domestic use, or free from serious objection.*

Results of examination of samples of subsoil water. Objection for domestic use to wells sunk in polluted soil.

The samples of water collected above the effluent-outfalls, from the rivers into which the effluents from the several sewage farms are discharged, varied considerably. They would all have been condemned bacteriologically from the point of view of drinking water. Even from the point of view of non-drinking water streams their condition was not always satisfactory, either chemically or bacteriologically. Below the effluent outfalls the mixed liquid (river water and effluent) was, under the circumstances, usually not unsatisfactory (*see* Parts II. and III., Chemical and Bacteriological Reports). Generally speaking, the discharge of the effluents into the respective streams did not exercise any marked prejudicial effect on the water of the stream; indeed, the reverse was sometimes observed. There seems to be no reason to doubt that the effluents from properly-managed sewage farms would, when discharged into non-polluted streams of relatively large volume, neither give rise to any nuisance, nor, so far as may be judged by rate of absorption of oxygen, prove injurious to fish.

Chemical and biological qualities of the river water above the effluent outfalls.

The samples of storm water† examined were almost invariably found to be most impure, both chemically and biologically. The samples of "street washings" (separate system) were all impure biologically, notwithstanding that some of them were fairly pure organically from the chemical point of view and withstood the incubation test under laboratory conditions of experiment. The results, however, show that even when a street water is comparatively pure organically, it requires adequate settlement for grit, and, further, that the liquid may be very impure even after long-continued rain. The practical advantages of the separate system may be great, and doubtless storm overflows are necessary; but the fact that storm liquids may be so impure, both chemically and bacteriologically, is a point of considerable importance (*see* Parts II. and III., Chemical and Bacteriological Reports).

Chemical and biological qualities of storm water and "street washings."

---

* Two years' work by one of us on the chemical and biological qualities of the Chichester well waters showed that shallow wells sunk in polluted soil and subsoil may show, on searching bacteriological examination, unequivocal evidence of excremental and, therefore, potentially dangerous pollution.

† As regards storm water, we draw here on the experience gained by the chemical and bacteriological examination of samples of storm water kindly sent us by Mr. Tatton from different places in the Mersey and Irwell watershed. These additional records are not given in much detail in this Report.

Basis for calculating work done by land.

In defining the work done by land in purifying sewage, the usual way of speaking of "population per acre" is open to the objection that the volume of sewage per head per day may, and does, vary to a considerable extent at different places, and that a large volume of sewage per head of the population does not *always* mean a correspondingly weak sewage (*see* Rugby and Aldershot Camp). The best way, in our opinion, of recording the work done by land is to speak of the number of gallons of sewage (exclusive of storm water) treated per acre per 24 hours (*a*) on the "working"* area, and (*b*) on the total irrigable area (working and "resting" areas), together with notes as regards the organic strength and other characters of the sewage, the amount of storm water dealt with on the farm, and the depth and quality of the soil and subsoil (*see* Section II. of this Report).

Comparison of terms.

The old terms "intermittent downward filtration" and "broad irrigation," for the reasons previously stated, have been replaced by the terms "land filtration" and "surface irrigation" (*see* Section II. of this Report).

Can land purify sewage indefinitely? Disposal of sludge.

Special attention must be directed to the length of time some of the farms have been in operation (five of them for over thirty years), and to the fact that some of them have disposed satisfactorily of their sludge on the farm during the whole period of their existence as sewage farms. Further, that most of them, year by year, have been called upon to treat an increasing volume of sewage without corresponding enlargement of their irrigable area. There seems no reason to doubt that, with proper management, land can purify sewage for a practically indefinite period (*see* Section II. of this Report).

Screening and settling.

We are of opinion that sewage before it is applied to land should be efficiently screened and settled, unless it is already in a thoroughly disintegrated condition. Where the sewage is fresh, especially in the case of heavy clay soils used as surface irrigation farms, this is very necessary. Porous sandy soils, however, worked as filtration farms, can in some instances without apparent detriment receive sewage in the raw condition, and some observers consider that their efficiency is, if anything, increased thereby. But there is always the possibility of nuisance arising in this way. As regards chemically-precipitated sewage and sewage treated by artificial processes antecedent to delivery on land, our data are insufficient to pronounce a decided opinion; but the views generally expressed by the witnesses called before the Commission are, no doubt, correct, namely, that land can deal directly with raw sewage, but it is better first to separate the solids mechanically; and, if the sewage of a large town has to be applied to a limited area of land, it may be advisable first to treat it chemically, or to pass it through bacteria beds (*see* Section II of this Report).

Trade refuse.

As regards trade refuse, the only two farms kept under observation where trade refuse was present in any quantity in the sewage, were Leicester ($\frac{3}{4}$ domestic, $\frac{1}{4}$ trade refuse), and Nottingham ($\frac{4}{7}$ths domestic, $\frac{3}{7}$ths trade refuse). The effluents from Nottingham were remarkably good; and those from Leicester fairly satisfactory, considering the available irrigable area, the nature of the soil, the method of treatment, and the volume of sewage being dealt with. Nevertheless, we do not assume from this that trade refuse (especially some kinds), if present beyond a certain proportion, may not seriously inhibit, if not prevent, the purification of sewage by treatment on land. On this point several of the witnesses before the Commission spoke somewhat strongly from personal knowledge and observation (*see* Section II. of this Report).

Are sewage farms a source (direct or indirect) of danger to health? Questions relating to stock and farm produce.

As regards the likelihood of sewage farms being dangerous to health, we can do no more than tentatively express the opinion that no convincing proof has yet been furnished of *direct* or wide-spread injury to health in the case of well-managed farms. It may be possible that the foul emanations from a badly managed or over-sewaged farm constitute an indirect source of danger to health by lowering the vitality of weakly and susceptible individuals.

---

* By "working" area is meant that portion of the total irrigable area which is actually being sewaged at one time.

Further, even sentimental considerations are not to be ignored in this matter, and the alleged depreciation in the value of house property due to the proximity of sewage farms is, if true, a serious question. We are, therefore of opinion that, subject to practical considerations, sewage farms in the neighbourhood of populous districts are liable to objection. In this connection the probably beneficial effect of a surrounding belt of shrubbery and trees has not, perhaps, been sufficiently recognised. As regards the produce from sewaged land, we are, on the whole, not in favour of sewage farms being utilised for the raising of crops for human consumption, however remote may appear the danger to health. But in respect of stock the case is different; and although we think it a wise precaution to keep cattle off recently sewaged land, we see no reasonable objection to stock being fed on the produce of antecedently sewaged land. But whenever there is a likelihood of the spores of B. Anthracis being present in the sewage,* special precautions should certainly be taken as regards the grazing of animals on land " treated " therewith.

Questions of profit or loss; cropping, etc.

Although we are of opinion that sewage farms in general can never be expected to show a profit if interest on capital expenditure is included, the fact that in favourable seasons some of them can more than cover the working expenses is a point in favour of cropping in connection with the land treatment of sewage. Moreover, in our opinion, cropping makes for purification, given good management, a volume of sewage not out of proportion to the average area under sewage at one time, and a suitably large "resting" area. We are not in favour of sewage farms being let; unless the irrigable area is very large, a tenant must sometimes be placed in the awkward position of having to choose between damaging a crop on the one hand, and purifying sewage imperfectly on the other.

Management of sewage farms.

It is impossible to lay too much stress on the importance of farms being well managed; but in this connection we desire to state that farm managers have usually a most difficult part to play, and no amount of care and attention will ever enable land, of any kind, to deal with a volume of sewage out of all proportion to the effective purifying area of the soil. We recommend that farm managers should be taught some simple test or tests to enable them to follow for themselves the operations of the land; that their instructions should be in writing, and should include a definite order to consider the farming results as quite secondary to "turning out" uniformly a satisfactory effluent; that the statistics of the farm should be most carefully kept; and that, wherever possible, the flow of sewage and of storm water should be gauged throughout the year. In the case of all large sewage works, permanent provision should most certainly be made for recording, by some reliable method of gauging, the daily flow of sewage. Meteorological observations are also of importance. For example, a comparison between the curves of the air and of effluent temperatures may afford a useful indication of the amount of filtration that is taking place on the farm [*see* Part IV. (Engineering and Practical Report) and Appendix A of this Report].

Questions of temperature in relation to the land treatment of sewage.

During the period of our investigations no opportunity occurred of watching the working of sewage farms during a prolonged period of exceptionally frosty weather. Nevertheless, on a number of occasions the weather was very cold, and the temperature of the air frequently sank below the freezing point. During these periods the ordinary working of the farm was not, so far as could be seen, seriously interfered with, and no lasting or marked deterioration of the effluents was observed. Although we are of opinion that temperature is a most important factor in purification, the range of temperature at which the bacteria concerned in sewage purification work is so wide that it can but seldom happen in this country that their vital activity is more than temporarily restrained.

---

* Compare Report on the presence of Anthrax at Yeovil in (1) septic tank liquor; (2) septic tank sludge; (3) primary coarse coke bed; (4) secondary fine coke bed; (5) general effluent from final catchpit in a hide factory; (6) mud of river Yeo; and (7) mud of Yeo Brook. (*See* Second Report of Royal Commission on Sewage Disposal: 1902, Cd. 1178.)

Surface irrigation farms suffer most in this respect, although, if the frost is sufficiently prolonged, filtration farms may also become affected. As explained elsewhere, the temperature of the effluents from surface irrigation farms varies almost in direct correspondence with the air temperature, whereas the temperature of the effluents from filtration farms is mainly governed by the temperature of the soil (*see* Part IV., Engineering and Practical Report). The witnesses examined before the Commission expressed on this subject the most contrary views, but we agree with those who stated that frost and snow do not usually prevent, although they may retard, purification of sewage by treatment on land. Nevertheless, we think that frost, if exceptionally severe and prolonged, may prove a serious hindrance to *effective* purification, more especially on surface irrigation farms

Nature of crops best adapted for sewage farms.

We have already expressed the opinion that cropping may be advantageous. As regards the nature of the crops, cereals are, practically speaking, inadmissible on that portion of the irrigable area which at some time or other during the year's working of the farm is meant to be sewaged. The best crops are those which can be more or less continuously sewaged without detriment, *e.g.*, quickly-growing plants like rye-grass, mangold-wurzel, prickly comfrey, etc. (*see* Part IV., Engineering and Practical Report).

Storm water and fixed overflows.

The question of storm water and fixed overflows is a most difficult one. Some of the witnesses examined before the Commission expressed the view that where storm water is to be dealt with on the land, the area of land required must be calculated upon the maximum volume of sewage that may be brought to the farm. Without in any way dissenting from this proposition in the abstract, it may be pointed out that if provision were made for treating at any one time sewage and storm water equal in amount to six times the dry weather flow of sewage, and if the basis for calculating the area required for purifying storm water were the same as for ordinary sewage, the surplus irrigable area on all farms would have to be increased to a serious extent. At first sight a feasible proposition would seem to be to reckon the extra area of irrigable land on the theoretical volume of liquid in excess of the dry weather flow capable, as the result of storms (if no overflows were in existence), of being brought to the works during the year. Then, if the "resting" area of the total irrigable area of the farm were sufficiently large in relation to the "working" area, any sudden fluctuations due to storm water could possibly be dealt with satisfactorily. But we do not know of any reliable way of calculating the yearly volume of storm water under the present unsatisfactory condition of matters as regards the absence, generally speaking, of apparatus to gauge by some efficient automatic method the daily flow of sewage throughout the year. As a matter of fact, on most farms considerable difficulty is experienced in dealing satisfactorily with the dry weather flow of sewage, and any large increase in the volume of sewage may mean the discharge into the river either of untreated sewage diluted with storm water, or of imperfectly purified effluents. The dry weather flow of sewage is reckoned on the flow during the whole 24 hours, but the difference between the maximum and minimum flow during the 24 hours is usually considerable. Hence, if a storm overflow be fixed at six times the average dry weather flow, it follows that during certain periods of the day a storm may cause the sewage to overflow with much less than an increase of six times the flow during these periods, and further, that the overflow might not come into operation during certain periods of the night, although the storm water may have increased the then flow ten or more times. Yet the liquid in the former case must be more foul than in the latter case. Of course, it will be said that if the increase of flow during the night does not reach the overflow cill, there is no reason why it should not be treated on the farm. This may be true, but it must be remembered also that the ability of a farm uniformly to yield good effluents probably depends in no small degree on the *comparative* rest afforded the land during the night.

Existing sewers are seldom large enough to carry off satisfactorily up to six times the dry weather flow of sewage, still less all the storm water in extreme cases, and if in the case of new sewerage schemes this were remedied, the cost would be serious, and the sewers would be large in relation to the dry

weather flow of sewage, and disproportionately large in relation to the periods of minimum flow of sewage. Assuming, however, the possibility and practicability in all cases, of a volume equal to six times the dry weather flow being brought to the farm, we consider that the difficulty of treatment would be lessened by: (1) increasing the capacity of the settling tanks; (2) having a larger "resting" area (*not*, however, at the expense of the "working" area, but by enlarging the total irrigable area); and (3) in particular cases by laying out portions of the land in special ways, *e.g.*, lagoons, storm water filters, etc., which need not be described here, since these matters would be determined by the local conditions.

The difficulty of treating storm water is largely an emergency one. As regards 1 and 2 above, by increasing the capacity of the settling tanks the effect of sudden fluctuations in the volume due to storm water would be in some measure controlled; the provision of a large "resting" area would tend to prevent the normal "working" area from being over-pressed during storms, as the former could be temporarily utilised to treat the increased volume of liquid. As regards (3), the subject is so wide, and depends so much on local circumstances, that it would be unwise to consider the matter further here.

So far as our observations go, the effluents from sewage farms treating a large proportion of storm water do not deteriorate to any marked extent; they may even show a temporary improvement during periods of wet weather. But during wet weather the normal working of the farm may be seriously embarrassed, and it is difficult to estimate the ultimate effect of storm water on the quality of the effluents. Moreover, it must be remembered that a storm water effluent from land may be as pure or purer than an ordinary effluent, but that if the total bulk of the storm water effluent is several times in excess of the normal volume, the effect on the river water may be the reverse of satisfactory.

In this connection we desire again to emphasise the fact that neither chemically nor bacteriologically is mere dilution synonymous with purification. Granting the impracticability of treating more than a certain proportion of storm water, it should be definitely understood that storm water is diluted, not purified, sewage [*see* Parts II., III. and IV. (Chemical, Bacteriological, and Engineering Reports)].

Rate of intermittency.

We have already expressed our opinion that the data available are insufficient to enable us to give any definite statement as to the best rate of intermittency either as regards filtration or surface irrigation farms. By "rate of intermittency" is meant, of course, whether the alternate periods of working and resting the land should occur at short or long intervals. It is obvious that if the alternations be too frequent, the "resting" area may not have time to recover its full purifying capacity before it is again sewaged, and, on the other hand, if the alternations be too infrequent, the "working" area may be rendered sewage-sick; meanwhile the "resting" area would be lying idle, long after it had recovered its purifying ability. A competent manager finds out by experience the best way of working the farm under his care; but it is desirable that the matter should be investigated experimentally, so as to enable certain general rules to be laid down for the preliminary guidance of persons responsible for the management of sewage farms (*see* Section II. of this Report).

Ratios of (1) total irrigable area and total acreage; and (2) "resting" and "working" areas of the total irrigable area.

As regards the ratios between (1) the total irrigable area and the total acreage, and (2) the "resting" and "working" areas of the total irrigable area, we have previously pointed out at some length that the first consideration is to have (*a*) the "working" area (*i.e.*, the area under sewage at one time) large enough to purify efficiently the whole volume of sewage which is being treated. Secondly, that (*b*) the "resting" area should be greater in the case of surface irrigation farms than for filtration farms. The ratio of (*a*) to (*b*) at Beddington was 1 in 6, and at Nottingham 1 in 2. Without venturing to lay down any fixed rule, we think that a ratio of about 1 in 5 and about 1 in 3 as regards surface irrigation and

filtration farms, respectively, is desirable ; but the above statement is based on too limited a number of observations to be of much value. A large "resting" area is especially necessary when much storm water is treated on the farm. Thirdly, that the surplus acreage (that is, the area representing the difference between the total irrigable area and the total acreage) should be ample. At Altrincham the surplus acreage was 53 and at Rugby 12 per cent. At the present time Altrincham is taking advantage of its relatively large surplus acreage, and is laying out a portion of it as an addition to the irrigable area (*see* Section II. of this Report).

Separate or combined sewerage system

As regards the respective advantages and disadvantages of separate and of combined sewerage systems, reference must be made to Section II. (particulars relating to each of the eight sewage farms kept under detailed observation). We may, however, again point out that the liquid carried away by the separate system is not, so far as our few analyses go, in a fit state to be discharged without treatment into any river.

Suitability of different kinds of soil.

The witnesses examined by the Commission as to suitability of different soils expressed very divergent views, some of them considering certain kinds of soil quite unsuitable, while others were of opinion that any kind of soil is capable of purifying sewage. Nearly all of them were agreed that light sandy loam overlying gravel and sand was the best type of soil for the purpose, while chalk, clay, peat and water-logged soils were regarded as either less suitable or as altogether unsuitable for sewage purification.

Upon this point we may, at the risk of repetition, shortly summarise our own experience.

A.—*Filtration.*

1. Excellent results can be obtained from light loamy soil overlying a porous subsoil.

2. A sandy soil and subsoil are also capable of yielding good results.

3. The same may be said of a partially peaty soil overlying gravelly sand.

4. Peat pure and simple is not well adapted for sewage purification.

5. With regard to Chalk, we can hardly speak with confidence, more data being required. The few (artificially obtained) effluents which we examined from a chalk farm had percolated *in about a minute and a half* through approximately 3 feet of chalk (from which the surface soil had been removed); in so doing they had undergone comparatively little purification organically, although the liquid in its passage dissolved out a large quantity of nitrate—the product, no doubt, of the oxidation of sewage matter* run on at a previous time. The purification would, of course, have been better had the surface soil also taken its part. But the above very rapid rate of filtration of sewage through the fissured chalk emphasises the necessity for carefully considering any possible connection that may exist between a sewage farm on Chalk and a water supply.

B.—*Surface Irrigation and Combined Surface Irrigation and Filtration Farms.*

Heavy loam and clay soils, although not so well suited for sewage purification purposes, may, in our experience, yield fairly good effluents if the volume of sewage treated per acre is relatively small.

Thus, almost any kind of soil can be used for the purposes of sewage purification, provided, of course, that the volume is proportionate to the purifying capacity of the soil in question. In certain cases, no doubt, this volume would be so small as to render the particular method of treatment impracticable, but where the line should be drawn it is difficult to say. The price

* Whether this nitrification had gone on solely in the surface soil or also in the chalk itself we cannot say.

of land and other local conditions must needs influence this question of practicability. We are far from advocating the treatment of sewage upon land which is, practically speaking, not well suited for the purpose, but this does not invalidate the truth of the proposition, that the matter is nearly always one of *degree* of suitability, and seldom one of intrinsic disability. In reference to this, we would lay stress on the good quality of the best effluents obtained from all the eight sewage farms kept under detailed observation.

Volume of sewage per acre. Population per acre.

A divergence also showed itself in the opinions of witnesses with respect to the question of population and of volume of sewage allowable per acre. Some of them considered that the maximum limits should be 5,000 gallons per acre per 24 hours for an irrigation farm, and 30,000 gallons for a filtration farm. Allowing 40* gallons of sewage per head per day, this works out to 125 and 750 persons per acre respectively. On the basis of population, other witnesses gave 100 to 1,000 persons per acre as the working limits, the number varying with the process of treatment adopted, the nature of the soil, and other factors. Converted into volumes of sewage per head per 24 hours (at 40 gallons per head), this gives 4,000 to 40,000 gallons per acre.

Others, again, suggested the following figures for population per acre :—

——	Crude sewage.	Precipitated or mechanically settled sewage.	Sewage after preliminary treatment on bacterial filters.	
Surface irrigation -	50 to 100	100 to 500	300 to 1,000	persons per acre.
Filtration - - -	75 to 150	200 to 500	400 to 1,000	

Again assuming 40 gallons of sewage per head per day, the above figures may be expressed thus :—

——	Gallons of crude sewage per acre direct on to land.	Gallons of sewage per acre after precipitation or settlement.	Gallons of sewage per acre after bacterial filters.
Surface irrigation - -	2,000 to 4,000	4,000 to 20,000	12,000 to 40,000
Filtration - - -	3,000 to 6,000	8,000 to 20,000	16,000 to 40,000

Broadly speaking, therefore, the various witnesses examined placed the extremes at 50 persons or 2,000† gallons per acre per 24 hours, and 1,000 persons or 40,000 gallons per acre per 24 hours.

Taking the eight principal farms kept under detailed observation for the Commission :—

1. As regards *population*, it is to be noted that, as previously explained in Section II., and again set forth in the table which follows, the filtration farms were dealing with the sewage of 166 persons (Aldershot Camp) to 675 persons (Cambridge) per acre ; and the combined surface irrigation and filtration farms with the sewage of 138 persons (South Norwood) to 238 persons (Beddington).

2. Taking *volume* alone, (*a*) the gallons of sewage actually being treated per acre of the "working" irrigable area per 24 hours varied from 23,300 (Nottingham) to 121,400 (Cambridge) in the case of filtration farms, and from

* This figure of 40 gallons is taken because it was the average volume at the eight principal sewage farms kept under observation. According to some statistics collected recently by our colleague, Mr. Colin C. Frye, it is probably not far from the mean for towns and cities with a population of 10,000 to 100,000, and over, though much too high for small towns and villages. It is brought forward here for comparative calculations only.

† It is difficult to see how this small volume could be satisfactorily spread over an acre of ground.

12,000 (South Norwood) to 57,100 (Beddington) in that of the combined surface irrigation and filtration farms. (*b*) The gallons of sewage treated per acre per 24 hours on the total irrigable area ("working" and "resting" areas together) varied from 8,300 (Aldershot Camp) to 30,400 (Cambridge) in the filtration farms, and from 4,000 (South Norwood) to 9,500 (Beddington) in the combined surface irrigation and filtration farms.

Comparative figures.

The following table gives all those figures for the eight sewage farms:—

	Sewage Farm.	Method of Treatment.	Population per acre irrigated.	Gallons of Sewage (exclusive of storm water) treated per acre per 24 hours.	Gallons of Sewage treated per acre per 24 hours on the assumption that each acre of the irrigable area is under Sewage all the year round.
Filtration Farms.	Cambridge ... ... (mainly domestic sewage; sandy loam overlying gravel and sand)	Screening, settling tanks and land filtration	675	121,600	30,400
	Nottingham ... ... (mixed sewage; light sandy loam and gravel, overlying gravel and sand)	Screening (partial) and land filtration	397	23,300	10,750
	Altrincham ... ... (domestic sewage; peaty soil lying upon sand and gravel)	Settling tanks and land filtration	514	46,000	23,000
	Aldershot Camp ... ... (purely domestic sewage; sandy soil and subsoil)	Screening, settling tanks and land filtration	166	25,000	8,300
Combined Surface Irrigation and Filtration Farms.	Beddington (Croydon) ... ... (mainly domestic sewage; gravelly loam over gravel and sand)	Screening, combined surface irrigation and filtration	238	57,100	9,500
	Rugby ... ... (mainly domestic sewage; heavy loam overlying stiff clay)	Screening, settling tanks, occasional precipitation, combined surface irrigation and filtration	171	42,800	8,500
	Leicester ... ... (mixed sewage; stiff clay soil overlying dense clay)	Screening, settling tanks, combined surface irrigation and filtration	146	21,500	5,370
	South Norwood... ... ... (purely domestic sewage; clay soil resting on London clay)	Screening, settling tanks, combined surface irrigation and filtration	138	12,000	4,000

But a comparison of such figures as are given in the foregoing tables merely brings into further relief the need for fortifying with additional data the terms "filtration," "broad irrigation," "method of treatment," etc. which, taken alone, are insufficient. Thus, (1) when "filtration" is spoken of, it should be supplemented by notes of the depth of soil and subsoil, of their mechanical composition, their water-holding capacity, and, if possible, of the average rate of filtration of water through them. (2) "Broad irrigation" is clearly very different in degree when carried out over a shallow clayey soil resting on a stiff clay and on a fairly deep porous soil. The nature, depth, and mechanical composition of the respective soils are again wanted here. (3) The character and strength of the sewage to be treated should be ascertained, and the relative amount of organic matter which it is proposed to treat per acre might advantageously be plotted out (as in diagram 5). If a sufficient number of such instances were available for reference, the purifying capacity of a given soil for a

sewage of given strength ought to be deducible with a fair approximation to accuracy.

While our own investigations have not been sufficiently comprehensive to allow of any very definite conclusions being drawn with regard to these points (or with regard to the best ratio between the "working" and "resting" areas and the rate of intermittency), we can show the results obtained with certain soils, of which the mechanical composition has been experimentally determined, when treating sewages of known volume and strength under definite conditions of working.

A short summary of the results, as regards sewages and effluents, is given in the joint tables (chemical and bacteriological) of Section VII., while the particulars relating to the various soils are to be found in Section II., Sub-section 13, of this Report, and more fully in Part II., the Chemical Report.

The chief notes in this connection may be summarised as follows :— Summary.

In the first place, the best kind of soil for filtration purposes (*e.g.*, light sandy loam overlying gravel and sand) can certainly purify to a remarkable extent, at the rate of 23,000 gallons of a strong mixed sewage per acre per 24 hours (*a*) at a given time ; and over 10,000 gallons per acre per 24 hours (*b*) on the year's working of the total irrigable area (*see* Nottingham). Further, under (*a*) and (*b*) sets of conditions, over 100,000 and over 30,000 gallons respectively of a rather weak sewage can be purified to a fair although not to an altogether satisfactory extent (*see* Cambridge).

Secondly, with soil less well suited for filtration purposes (*e.g.*, sand and partially peaty soil lying upon sand and gravel), from about 25,000 to 46,000 gallons of sewage per acre per 24 hours (*a*) at a given time; and from about 8,000 to 23,000 gallons per acre per 24 hours (*b*) on the year's working of the total irrigable area, can be treated so as to yield effluents fairly good, but, on the whole, not quite satisfactory (*see* Aldershot Camp and Altrincham).

Thirdly, with soils passing from gravelly loam to heavy loam or clay, all being worked as combined surface irrigation and filtration farms, from about 12,000 to 57,000 gallons of sewage per acre per 24 hours (*a*) at a given time ; and from about 4,000 to 9,000 gallons per acre per 24 hours (*b*) on the year's working of the total irrigable area can be treated so as to yield effluents moderately good, but still not altogether satisfactory (*see* Beddington, Rugby, Leicester, and South Norwood).

To summarize all our results within the limits of a few sentences is impossible, but we may say in conclusion, and speaking in general terms, that we doubt whether even the most suitable kind of soil worked as a filtration farm should be called upon to treat more than 30,000 to 60,000 gallons per acre per 24 hours at a given time (750 to 1,500 persons per acre) ; or more than 10,000 to 20,000 gallons per acre per 24 hours, calculated on the total irrigable area (250 to 500 persons per acre). Further, that soil not well suited for purification purposes, worked as a surface irrigation or as a combined surface irrigation and filtration farm, should not be called upon to treat more than 5,000 to 10,000 gallons per acre per 24 hours at a given time (125 to 250 persons per acre); or more than 1,000 to 2,000 gallons per acre per 24 hours, calculated on the total irrigable area (25 to 50 persons per acre). It is doubtful if the *very worst* kinds of soil are capable of dealing quite satisfactorily even with this relatively small volume of sewage. The population per acre is calculated on 40 gallons of sewage per head per day. It is here assumed that the sewage is of medium strength, and is mechanically settled before going on to the land.

Comparing the above figures with the volume of sewage capable of being treated by artificial processes, we note that the witnesses examined by the Commission generally expressed the following opinion :—

Contact beds.—750,000 gallons per acre per 24 hours, allowing for periods of rest, but not for secondary treatment. Allowing one acre of secondary

bed for every two acres of primary bed, about 500,000 gallons per acre per 24 hours could according to this view be finally treated. It is assumed always that the sewage has been previously treated either by chemical precipitation, or by subsidence in settling tanks, or in a septic tank.

Continuous filters.—About 484,000 to 2,904,000 (4,840,000 according to one witness) gallons per acre per 24 hours. Previous treatment by chemical precipitation, or subsidence in settling tanks, or in a septic tank is assumed.

Apart from the question of the quality of the effluents, it is obvious that, generally speaking, a larger volume of sewage can be treated by artificial bacteria bed processes than by land.

APPENDIX A.

Management of Sewage Farms.

There can be no doubt that even the best of sewage farms, with the most suitable soil, will under continued bad management fail to turn out a satisfactory effluent.

The question of whether or not a particular farm is going to purify the sewage efficiently depends mainly upon the manager, assuming, of course, that the farm has been properly laid out in the first instance, that it has a reasonable volume of sewage to treat, and that the manager has (within certain limits) a free hand in the supervision of sewaging operations. The fact, however, must not be lost sight of that he has often a most difficult post to fill, especially with regard to the crops. The effectual purification of sewage, even with suitable land, can only be accomplished when the farming operations are relegated to the background and the production of a good effluent considered of primary importance. On the other hand, the manager knows that the crops will probably form an important item in his receipts at the end of the year, and he not unnaturally wishes it to appear that the farm is being worked economically under his supervision. Hence there is a temptation to grow remunerative crops, *e.g.* cereals, that cannot be sewaged (at all events for the greater part of the year), or to refrain from the further sewaging of crops which may be damaged thereby; meanwhile the land which is under sewage must needs yield, owing to the lack of rest, increasingly unsatisfactory effluents. There may of course be some farms where the large area at command in proportion to the volume of sewage to be "treated" renders the growing of grain crops justifiable, but these are exceptions to the general rule. Land is usually too expensive in the immediate vicinity of towns to allow of this, and the tendency is to take too little rather than too much land for a sewage farm.

Speaking generally, large farms are better managed than small ones, this being in great measure due to the fact that the salary attached to the latter does not always offer sufficient inducement to a competent man to undertake the duties. In many instances there are small districts fairly near together, each with its own sewage farm. In such cases a combined scheme would appear to be advantageous; by adopting this course an adequate salary could be paid so as to secure an efficient manager, while the annual cost of treating the sewage would also be lessened. On the other hand, it is possible to have a sewage farm so large as in a sense to be unwieldy.

It seems desirable that managers should employ day by day some simple chemical test or tests to enable them to follow the results of the working of the farm to the best advantage. It is probable that attention to this point would do much to foster the desire on their part to turn out the best effluent possible, at the expense, if necessary, of the crops. This question is raised quite apart from the larger one of appointing a qualified chemist in connection with all large sewage disposal works.

In the case of a new farm it would seem advisable, if practicable, that the prospective manager should be on the spot while the works were being carried out, as he would thereby obtain an insight into details which otherwise it might take him some time to discover (*e.g.*, the nature of the soil and subsoil on different parts of the farm, as disclosed by drainage operations). In connection with this, it may be remarked that the soil and subsoil are rarely uniform in nature throughout a farm, and that therefore the various plots cannot all take the same quantity of sewage.

We are unable to recommend the abandonment of farming operations even in connection with filtration sewage farms, because, if intelligently pursued, they make for profit with increased efficiency of the land. The farming operations, however, should always be under the control of the authorities responsible for the proper working of the farm, and the manager should receive written and explicit directions to regard the crops as of secondary importance to the uniform and satisfactory purification of the sewage.

It would be invidious to attempt to arrange in order of the excellence of the management the various farms, which by the courtesy of the Local Authorities and their Officers we have been enabled to keep under observation, but Nottingham Sewage Farm cannot be passed over without special comment. There can be no question that here the excellent management of the farm largely contributed to the remarkably good quality of the effluents.

ROYAL COMMISSION ON SEWAGE DISPOSAL.

SUPPLEMENTARY VOLUMES PRESENTED WITH THE

FOURTH REPORT

OF

THE COMMISSIONERS

APPOINTED IN 1898

TO INQUIRE AND REPORT WHAT METHODS OF

TREATING AND DISPOSING OF SEWAGE

(INCLUDING ANY LIQUID FROM ANY FACTORY OR MANUFACTURING PROCESS)

MAY PROPERLY BE ADOPTED.

VOLUME IV.

REPORTS TO THE COMMISSION BY DR. MCGOWAN, DR. HOUSTON, AND MR. KERSHAW ON LAND-TREATMENT OF SEWAGE.

PART II.—CHEMICAL REPORT BY DR. G. MCGOWAN.

Presented to both Houses of Parliament by Command of His Majesty.

LONDON:
PRINTED FOR HIS MAJESTY'S STATIONERY OFFICE,
BY WYMAN AND SONS, LIMITED, FETTER LANE, E.C.

And to be purchased, either directly or through any Bookseller, from
EYRE AND SPOTTISWOODE, EAST HARDING STREET, FLEET STREET, E.C.; and
32, ABINGDON STREET, WESTMINSTER, S.W.; or
OLIVER AND BOYD, EDINBURGH; or
E. PONSONBY, 116, GRAFTON STREET, DUBLIN.

1904.

[Cd. 1886—I.]

Presented by

Purchased

October 1908

LAND TREATMENT OF SEWAGE.

PART II.

CHEMICAL REPORT

BY

G. McGOWAN.

NOTE.—These Reports to the Commission on Land Treatment of Sewage are published in four parts, viz. :—

Part I.—General Report by Dr. G. McGowan, Dr. A. C. Houston, and Mr. G. B. Kershaw.

Part II.—Chemical Report by Dr. G. McGowan.

Part III.—Bacteriological Report by Dr. A. C. Houston.

Part IV.—Engineering and Practical Report by Mr. G. B. Kershaw.

6225 (ii.). 1500.—Wt. 26170. 9/04. Wy. & S.

EXTRACT FROM THE FOURTH REPORT OF THE ROYAL COMMISSION ON SEWAGE DISPOSAL. (1904. Cd. 1883)

ERRATA (in Diagrams).

Diagram 2, Sample 474. The centrifuge figure should be 258, not 158.

Diagram 5, Sample 303. The centrifuge figure should be 228, not 328.

Diagram 11, Sample 276. The centrifuge mark should be deleted.

Diagram 17 Sample 443. The centrifuge figure is 356.

6225 (ii).

TABLE OF CONTENTS.

	PAGE.
Introduction	1
Aldershot Camp Farm	7
Altrincham Farm	45
Cambridge Farm	65
Croydon (Beddington) Farm	91
Leicester Farm	127
South Norwood Farm	155
Nottingham Farm	195
Rugby High Level Farm	215
Dr. Poore's Village System	241
Derby County (Mickleover) Asylum Farm	243
Hemsworth Farm	247
Lindfield Farm	249
Luton Farm	251
Sandhurst Farm	263
Woking Farm	265
Worsley Farm	267
Mechanical Analysis of Soils and Subsoils	275
Lime in Soils and Subsoils	300
Summary of Chemical Results and Conclusions	303
Quality of Sewages and of Effluents	303
Summary of Results at the different Farms	304
Average Composition of the various Sewages	310
Average Composition of the various Final and General Effluents	312
Some average Ratios of Analytical figures from the Sewages and Effluents	314
Brook and River Waters,—Summary of Results	318
Subsoil Waters,—Summary of Results	320
Storm Waters,—Summary of Results	321
Surface Street Washings,—Summary of Results	321
Artificial Storm Waters,—Summary of Results	322
Chemical Standards of Purity for Sewage Effluents	325

REPORT

TO THE

ROYAL COMMISSION ON SEWAGE DISPOSAL, BY DR. McGOWAN, ON LAND-TREATMENT OF SEWAGE.

INTRODUCTION.

In the following Chemical Report upon the Land Treatment of Sewage, the eight principal farms of which a more or less detailed study has been made for the Commission are taken in alphabetical order, but for purposes of comparison they may be divided roughly into the two following groups, viz. :—

A.—*Filtration Farms.*

Aldershot Camp.
Altrincham.
Cambridge.
Nottingham.
Croydon, Beddington (a small part of the farm).

B.—*Surface Irrigation Farms* (i.e., *mainly Surface Irrigation*).

Croydon, Beddington (the greater part of the farm).
Rugby.
Leicester.
South Norwood.

The individual farms in each of these two groups are more or less comparable with one another.

Following these principal farms, again in alphabetical order, come those other farms at which only a comparatively small number of observations were made.

The sectional arrangement adopted is the same throughout, viz., the Report on any one farm is followed by the Tables of Analysis on which that Report is based, and these in their turn are succeeded by diagrams which give the curves of the more important analytical figures in (*a*) the sewages; (*b*) the effluents ; and (*c*) the brook or river waters at the farms. The diagrams are confined to the eight principal farms, the others having merely Report and Table of Analysis.

Further, to facilitate a comparison of the results obtained at different places, the arrangement of the matter is as far as possible the same throughout this Report. After briefly indicating the system followed at a farm—these notes being for the most part taken from the corresponding Engineering Report*—there are given the figures of the mechanical analysis of the soil and subsoil, and after that the sections dealing with sewage, effluent, and river water respectively.

In the Tables of Analysis the samples follow one another as far as may be in numerical order, excepting that the hourly sewage samples always come at the beginning and the brook or river waters always at the end. Strict adhesion to this order was, however, impossible, for reasons which are at once apparent on consulting the index prefixed to each Table of Analysis.

Besides these regularly recurring sets of samples, the Tables of Analysis also contain the figures obtained from the examination of a few subsoil (or well) waters, surface street washings, and "artificial storm waters," all of which are referred to either in one or another of the Farm Reports or in the *Summary of Conclusions* at the end of the whole.

Mr. Kershaw's "Notes on Samples," which are to be found in the Engineering Report* under the respective farms, describe in a few words the conditions under which any particular sample was drawn ; they should, therefore, be referred to by anyone who studies the Tables of Analysis.

---

* Part IV. Engineering and Practical Report, by Mr. G. B. Kershaw.

9.

All details referring to *methods of analysis* are discussed in a separate Report on the subject.* It is therefore only necessary to explain a few of the points very briefly here.

All the figures given in the Tables of Analyses are expressed in parts per 100,000, by *weight*, excepting those referring to (a) solids (*i.e.*, mud) as determined by the centrifuge, which are in parts per 100,000, by *volume*, and (b) those referring to dissolved gases, which are in parts per 1,000, by *volume* or c.c. per litre (at normal temperature and pressure). Further, the various nitrogen compounds are all expressed in terms of nitrogen, so as to be directly comparable with one another. This was the system which was recommended a few years ago by a joint committee made up of a committee appointed by the British Association to report upon the subject and a representative of the Commission. It would be a great convenience if this mode of expressing results were generally agreed to and adopted by chemists throughout the country and by managers of sewage farms or works, as such a course would greatly facilitate the reading and comparison of reports.

In every case, excepting where it is otherwise specified, the *whole* sample of a sewage or effluent—*i.e.*, liquid and solid together—has been taken for analysis. In the case of *sewages* it is this muddy liquid which the land has to treat, and in the case of *effluents* it is the resulting mixture (supposing suspended solids are present) which runs into brook or river. The point was carefully considered by the Commission at the time when systematic chemical work was begun for them, and the conclusion was arrived at that it represented better the actual state of affairs to analyse an effluent as it was actually discharged than to allow it to settle and then analyse the clear liquid. This, however, is subject to the slight modification in the case of effluents that the small amount of clear liquid required for the determination of dissolved oxygen by the copper chloride method (about 70 c.c. out of a total of 1,200–1,300 c.c.) was removed prior to shaking up the bulk. The effect of this would be to increase very slightly the apparent impurity in the effluent, but in most cases this increase would be so small as to be of no moment whatever.

Many more analytical data have been accumulated in the course of this investigation than are actually necessary for judging the character of a sewage or an effluent; that is to say, no one who has had experience in the matter would think of suggesting such detail in analysis for the daily conduct of a sewage work or farm. But in this instance it was thought well to carry on a number of different tests alongside of one another, in order to see how far they agreed or the reverse, and also in order that one estimation might act as a check upon another.

In some cases double analyses of the same sample (either from the same bottle or from two separate bottles) by two different workers are given. It so happened that when most of these double analyses were made there was some trouble from "albuminoid" ammonia in the distilled water. But, even allowing for this and for differences in sampling, there were some marked decrepancies in the analyses; however, most of the figures are given. They at least serve to indicate the desirability for an understanding among chemists with regard to more or less definite methods of analytical procedure.†

The term "corresponding" samples must be taken with reserve. Anyone who has had experience in drawing samples at sewage farms will at once appreciate this.

With regard to the actual analytical procedure itself, a few points may be referred to here:—

1. By "jointing" is meant putting a mercury seal upon the neck of a bottle containing liquid, in order to prevent ingress of air, the bottle being afterwards allowed to stand at laboratory temperature. When a sample was incubated, this was always done for 5 days (or more) at a temperature of 26·7° C. (80° F).

2. The term "sweet," which is often used to describe the condition of a sample after incubation, means that the liquid had a clean smell.

3. Excepting where it is otherwise stated, ammoniacal nitrogen has been determined in the ordinary way by distillation. While in certain cases an approximate determination of ammonia by *direct* nesslerization of the liquid is of distinct use, we have not as a rule been able to get good quantitative results in this way, partly, no doubt, because of the comparatively large amounts of lime in most of the effluents tested.

---

* Fourth Report of Royal Commission on Sewage Disposal: Vol. IV., Part V.—Report to the Commission by Dr. G. McGowan, Mr. R. B. Floris, and Mr. R. S. Finlow on Methods of Chemical Analysis as applied to Sewage and Sewage Effluents.

† *Cf.* Report on Methods of Chemical Analysis (Part V.).

4. (*a*) The earlier estimations of organic nitrogen by the (indirect) method of Kjeldahl, *with* reduction, were not always so good as the later ones, the process being gradually improved in small details as time went on. In the earlier samples, too (up to No. 226c), a small correction had to be made here for nitrite when the latter was present, though this correction was usually negligible. When the total organic nitrogen, determined in this way, came out as low or slightly lower than the albuminoid nitrogen, the figure for the latter has been taken as representing the organic nitrogen, though in all probability it is too low. The method being an indirect one is not applicable to very pure effluents, but on the other hand it is suitable for sewages, tank liquors and ordinary effluents, and it has the further great advantage of giving the figure for the total nitrogen present. It was intended to make a number of concurrent estimations of organic nitrogen by this method and by that of Frankland and Armstrong, but time did not permit of enough of these being done for a fair comparison.

(*b*) In the Kjeldahl method, *without reduction*, the organic nitrogen was arrived at by deducting the ammoniacal from the Kjeldahl nitrogen obtained by simple evaporation of the liquid with sulphuric acid (the determination of albuminoid nitrogen not being taken into account here). The results obtained by this latter method were very variable, probably for the reasons given under "Methods of Analysis." It appears, however, to be fairly applicable in certain cases (*cf.* the various Farm Reports).

5. The "oxygen absorbed" test with permanganate was done throughout at a temperature of 26·7° C. (80° F.), approximately, with a strong permanganate solution (3·94 grammes per litre).

6. *Incubator Test.*—As is seen by a reference to the separate Farm Reports and the Tables of Analysis, the effect of the Incubator test was judged in two ways, viz., (*a*) as Mr. Scudder does it—*i.e.*, by the difference in permanganate required before and after incubation at 26·7° C. (80° F.), and (*b*) by smell. The results show that Mr. Scudder's test was rather the more stringent of the two; at the same time, perhaps qualifying this, it has to be borne in mind that the error of experiment here is rather greater with the "at once" than with the "3 minutes'" test, and with strong than with weak permanganate.

7. *Smell of Effluents.*—Attention should be paid to the smell of an effluent when it is drawn, for it may in certain cases smell of sewage and yet contain a sufficient reserve of nitrate to keep it sweet upon incubation. Still, such an effluent would take up dissolved oxygen from surrounding water somewhat rapidly, and hence it cannot be considered as properly purified.

8. Pure cellulose—*i.e.*, the cellulose molecule—is not affected by acid permanganate, hence the "oxygen absorbed" test takes no account of any cellulose present in a sewage. For this reason the determinations of "cellulose" in the hourly samples of sewage are of considerable interest. As explained in detail in the Report upon Methods of Analysis* (which see), the figures obtained do not represent pure cellulose, but they are comparable with one another.

9. The volumetric determination of solids by the centrifuge is explained under "Methods of Analysis."* It is therefore only necessary here to remark that the "centrifuge solids" are really *muds* containing a large quantity of water. It will be seen that in an average settled sewage the volume of 1 gramme of suspended solids, as measured by the centrifuge, is about 6 to 7 c.c.; but the solids in the Aldershot Camp settled sewage were less flocculent than this, 1 gramme occupying a volume of about 5 c.c. In effluents which contain solids in suspension these are usually very flocculent also, but we have not sufficient data for an exact comparison here.

10. In those cases where the suspended solids of a sewage were examined and measured under the microscope, this was done with the sample which had been rendered uniform for analysis, the solids being therefore to some extent disintegrated.

11. For the determination of dissolved oxygen the earlier samples were boiled out, and the figures are to be taken as accurate, excepting that there was a *very slight*

* Report on Methods of Chemical Analysis (Part V.).

aeration up to sample No. 30 when filling the liquid into the boiling-out flask (this is practically negligible). In the later determinations the copper chloride method was used, in order to save time, but the results obtained by it are to be regarded as only very approximate in the case of coloured or turbid effluents; in some cases, too, the standard tubes were allowed to get too old (for details, see the respective Farm Reports and also "Methods of Analysis"). The significance of the actual quantity of dissolved oxygen in an effluent at the time of drawing may vary; it may mean much or little, according to circumstances. But the rate at which this is diminished between the time of drawing and analysis, or, to put it more generally, the rate of absorption of dissolved oxygen by an effluent is of fundamental importance, and this has been discussed in the section dealing with standards (see page 325).

12. With regard to the figures giving the numbers of particles in one gramme of soil, the number of the particles of organic matter present not being known, they have been neglected; hence both the total numbers of particles and the relative numbers refer to one gramme of ignited soil or subsoil. The same applies to the figures for the number of particles in one cubic centimetre of soil (*cf.* p. 293, first paragraph).

The question of standards of purity for effluents is dealt with in the *Summary of Conclusions* at the end of this Report, and reasons are given there why no fixed standard has been specified in the meantime; at the same time the considerations on which weight has been laid in judging the quality of the various effluents are detailed. Since, however, reference is frequently made to the well-known "oxygen absorbed" test, it should be borne in mind that this test has been throughout done for the Commission at a temperature of 26·7° C. (80° F.) with a rather strong permanganate solution (of the strength used by Mr. Dibdin), instead of at the lower temperature of 15·5° C. (60° F.) and with the weaker solution of permanganate which is generally employed. As done by us, therefore, the test is more stringent.* Reference is also frequently made, again for purposes of comparison, to a modification of Dr. Rideal's method of judging an effluent (according to the ratio of oxidised to unoxidised nitrogen in it), *i.e.*, to the ratio between oxidized nitrogen on the one hand and albuminoid and total organic nitrogen on the other. In the *Summary of Conclusions* reasons are adduced for favouring the adoption of a standard based—in great part at least—upon the rate of absorption of dissolved oxygen by an effluent.

For the convenience of those who are accustomed to gauge purification by the percentage diminution of albuminoid nitrogen and "oxygen absorbed" from permanganate, this calculation is given for each set of final and general effluents. But it must not be forgotten that the organic matter of a well purified effluent is quite different as regards fermentability from the organic matter of a diluted sewage showing the same figure for albuminoid nitrogen, and that therefore this calculation—while convenient—is purely empirical and unscientific. It is further to be borne in mind that in summer, at all events, the purification of sewage by land is really better than it appears to be on the basis of such a calculation, because of the concentration of the liquid due to absorption by plants and to evaporation.

I have thought it well, before discussing the farms separately, to insert here the following four diagrams, Nos. 1, 2, 3 and 4, which will be useful for reference to anyone reading the Report:—

Diagrams Nos. 1 and 2 show graphically the results obtained by the analysis of 29 sets of hourly samples of sewage, drawn in equal quantities per hour over the entire day, from the farms at Croydon (Beddington), South Norwood, Aldershot Camp, Nottingham, Leicester, Rugby and Cambridge. The portions of these curves which belong to any given farm are included in the sewage diagram of that farm, and the corresponding figures are criticised in the farm Report itself and also in the section of the *Summary of Conclusions* which deals with ratios; but, as it is interesting to contrast the strengths of the various sewages, and to trace the points of

* Since the foregoing was written, a considerable number of comparative estimations, made with effluents from artificial processes, have shown that the four hours' permanganate test is decidedly more stringent when a strong permanganate solution at the higher temperature is used. The well-known Mersey and Irwell *provisional* standard, using weak permanganate at 60° F., is 1·43 parts "oxygen absorbed" per 100,000; judging from the above-mentioned comparative estimations, the equivalent figure for this, when using strong permanganate at 80° F., would be about 2·4 or, at all events, rather over 2 parts per 100,000. (*Cf.* Vol. IV., Part V., Report on Methods of Chemical Analysis, pp. 40–41).

agreement and disagreement in the curves placed all together, the diagrams are appended here. (It will be seen, by referring to the separate Farm Reports, that rain interfered to some extent with these samples, more especially at Beddington and Cambridge).

Diagram No. 3 (*Engineering Report Diagram*), shows the depth in feet of sewage (exclusive of storm water) treated per acre of irrigable area per annum at the eight principal sewage farms which have been under observation, together with the average annual rainfall.

Diagram No. 4 indicates *approximately* the relative proportions of *organic matter* treated per acre of irrigable area upon the seven farms specified in it (no hourly samples of sewage were drawn at Altrincham, and so it cannot be included here), while the annexed table shows how this diagram was obtained.

Table of Figures shown in Diagram No. 4

Table showing approximately the relative amounts of organic matter in terms of albuminoid nitrogen, total organic nitrogen, total nitrogen, and oxidizable matter as measured by the four hours' "oxygen absorbed" test at 26·7° C. (80° F.), which are treated per acre of irrigable area on the seven undermentioned sewage farms, on the assumption—*for purposes of comparison*—that each acre of irrigable area is under sewage all the year round.

These figures are arrived at by multiplying the average figures obtained in the analysis of the *hourly* samples of sewage by the respective volumes treated per acre of irrigable area. They are merely *relative* figures, *not* parts per 100,000.

Name of Farm.	Gallons of Sewage per Acre of Irrigable Area	Albuminoid Nitrogen.	Total Organic Nitrogen.	Total Nitrogen.	"Oxygen Absorbed" from Permanganate.
Cambridge - - - - - -	30,400	2·77	5·7	17·4	30·7
Aldershot Camp - - - - -	8,300	1·34	4·2	11·0	17·3
Nottingham - - - - -	10,750	1·56	3·4	8·3	25·0
Rugby - - - - - - -	8,570	1·48	2·8	8·3	15·8
Croydon (Beddington) - - -	9,520	0·87	2·0	6·8	11·9
Leicester - - - - - -	5,370	0·64	1·3	4·4	12·0
South Norwood - - - - -	4,000	0·28	0·6	2·1	3·1

Note.—This table of figures and the corresponding diagram take no account of storm water, much more of which is treated at Beddington and South Norwood than at the other farms. Further, the inequalities due to drawing the hourly samples in equal volumes per hour, instead of in volumes proportionate to the rate of flow, would be greater in some cases than in others. For these reasons, the figures are only to be taken as approximate.

In conclusion I wish to express my great indebtedness to Mr. R. B. Floris, A.I.C., and Mr. R. S. Finlow, B.Sc., Chemical Assistants to the Commission, for the zealous and thorough way in which they have carried out by far the greater part of this work, and for many suggestions with regard to improvements in methods of analysis which are due to them. The larger share of the work falls to Mr. Floris, whose appointment dated earlier, but Mr. Finlow also did a great deal of it. Mr. Eric H. Richards, B.Sc., has also during the past year given most useful help, both in the analytical part of the work and in the preparation of the various diagrams, &c. Miss H. Chick, though not directly participating in the work of this Report, examined with me beforehand a number of the processes upon which it is based. Lastly, I would express my thanks to my colleague Mr. Colin C. Frye for many valuable suggestions, more especially as regards the taking of the hourly sewage samples, which latter was indirectly due to him.

GEORGE McGOWAN.

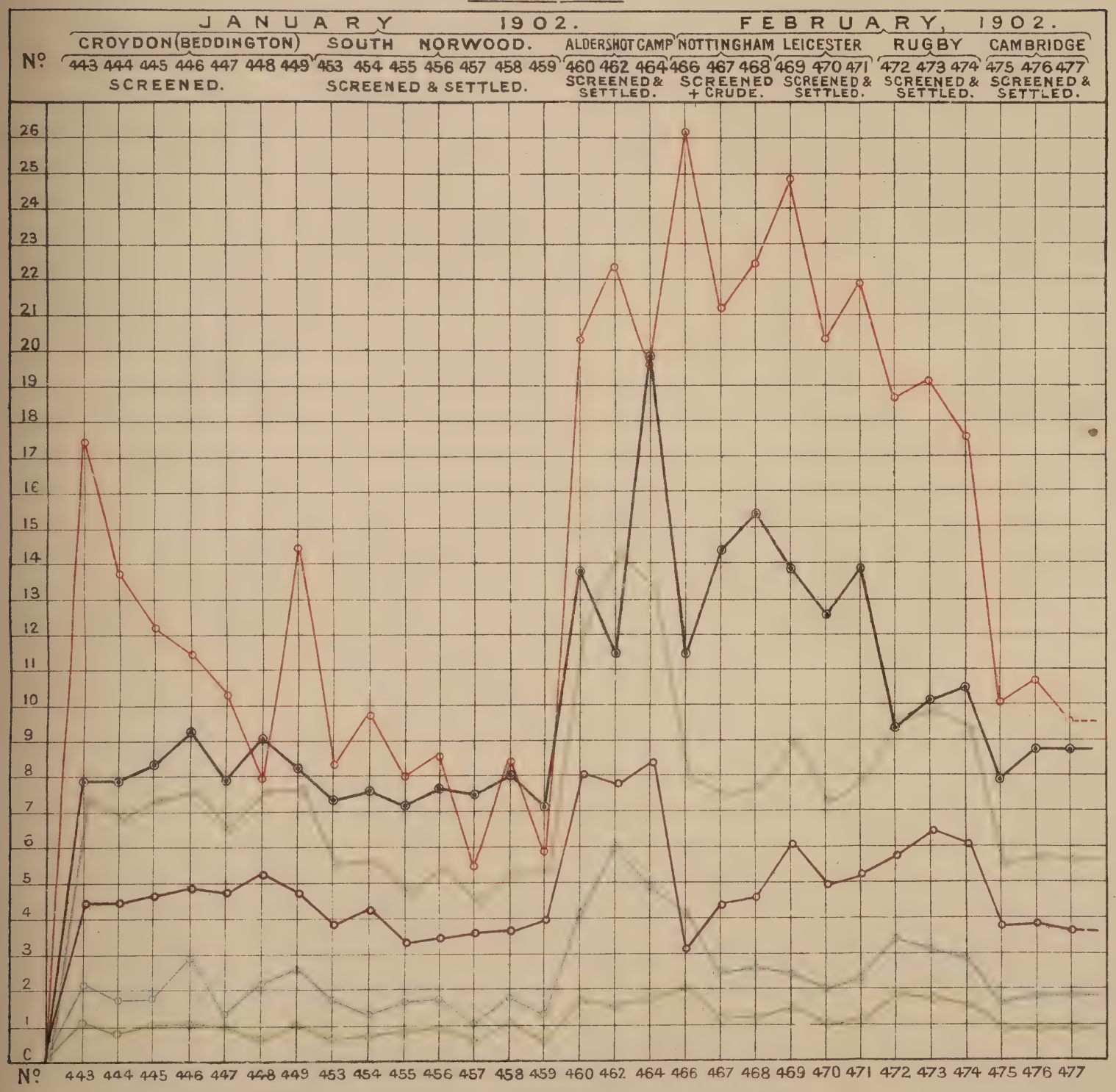
Ealing, London, W.

Diagram No. 1.

SEWAGE FARMS.

SETS OF HOURLY SEWAGE SAMPLES FROM SEVEN DIFFERENT FARMS. CURVES.

SHEET No. 1.



Note

Each sample number represents a mixture of 24 hourly samples, taken in equal quantities per hour.

REFERENCE

Parts per 100.000, by Weight.

Albuminoid Nitrogen ..... *Shewn thus* ———

Organic Nitrogen by Kjeldahl, with Reduction ..... ———

Ammoniacal Nitrogen ..... ———

Total Nitrogen by Kjeldahl, with Reduction ..... ———

"Oxygen absorbed" from Permanganate at 26·7°C (80°F.) in four hours ..... ———

Chlorine (Combined) ..... ———

Note

Figures in the Vertical line represent "Parts per 100.000."

Figures in the Horizontal line represent the numbers of the Samples analysed.

A dotted line is used when there is a break in the curve.

3332, 10. 02.

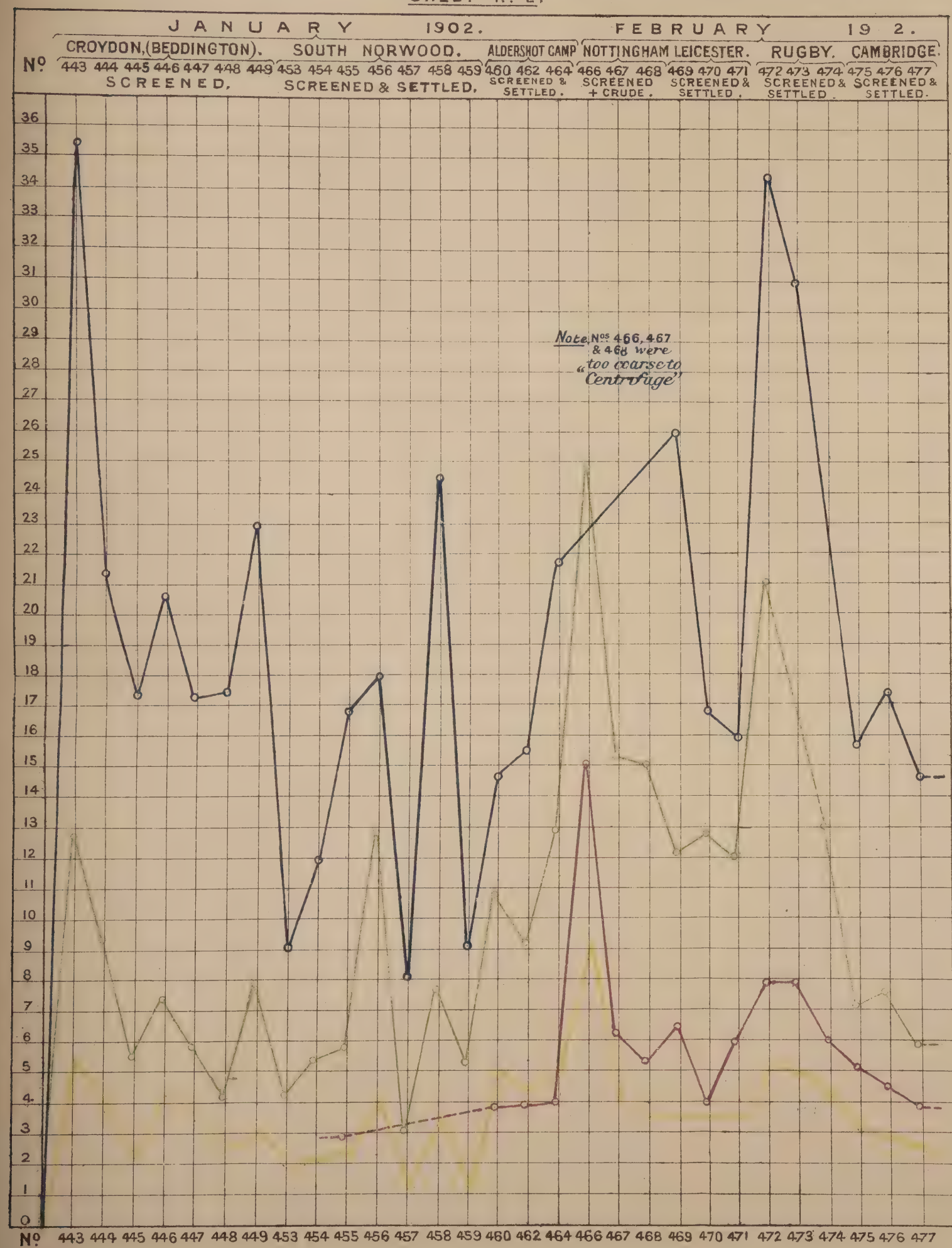
Weller & Graham Ltd Litho. London.

Diagram N 2.

SEWAGE FARMS.

SETS OF HOURLY SEWAGE SAMPLES FROM SEVEN DIFFERENT FARMS. CURVES.

SHEET Nº 2.



Note
Each sample number represents a mixture of 24 hourly samples, taken in equal quantities per hour.

REFERENCE

Parts per 100.000. by Weight.

Solids in Suspension (Gravimetrically) (Scale divided by 10)

Cellulose.

Cellulose (still containing fat).

Parts per 100.000. by Volume.

Solids in Suspension (by Centrifuge) (Scale divided by 10)

Note
Figures in the Vertical line represent "Parts per 100.000."

Figures in the Horizontal line represent the numbers of the Samples analysed.

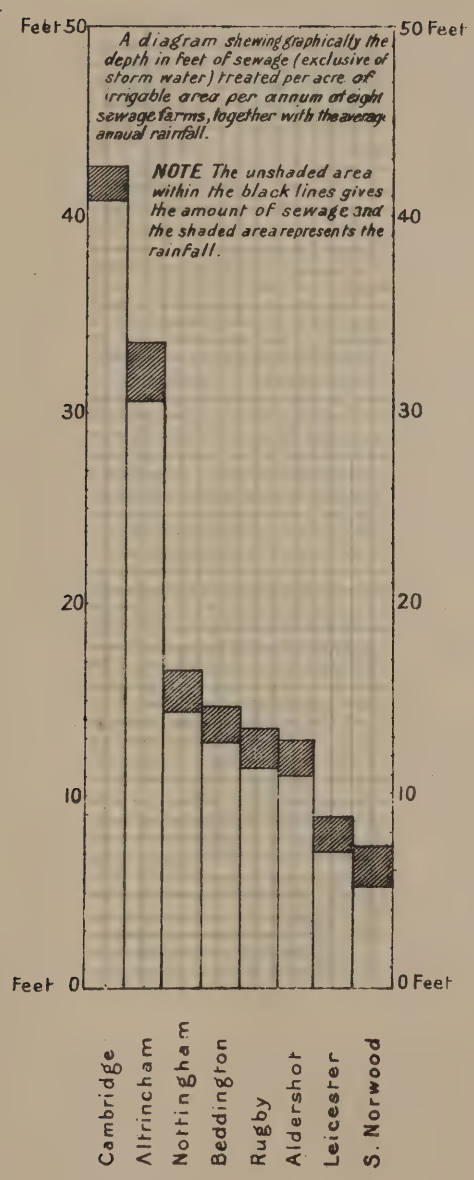
A dotted line is used when there is a break in the curve.

3332. 10. 02.

Weller & Graham Ltd Litho. London.

Diagram No. 3.

(Engineering Report Diagram)



Weller & Graham Ltd Litho. London

Diagram No. 4.

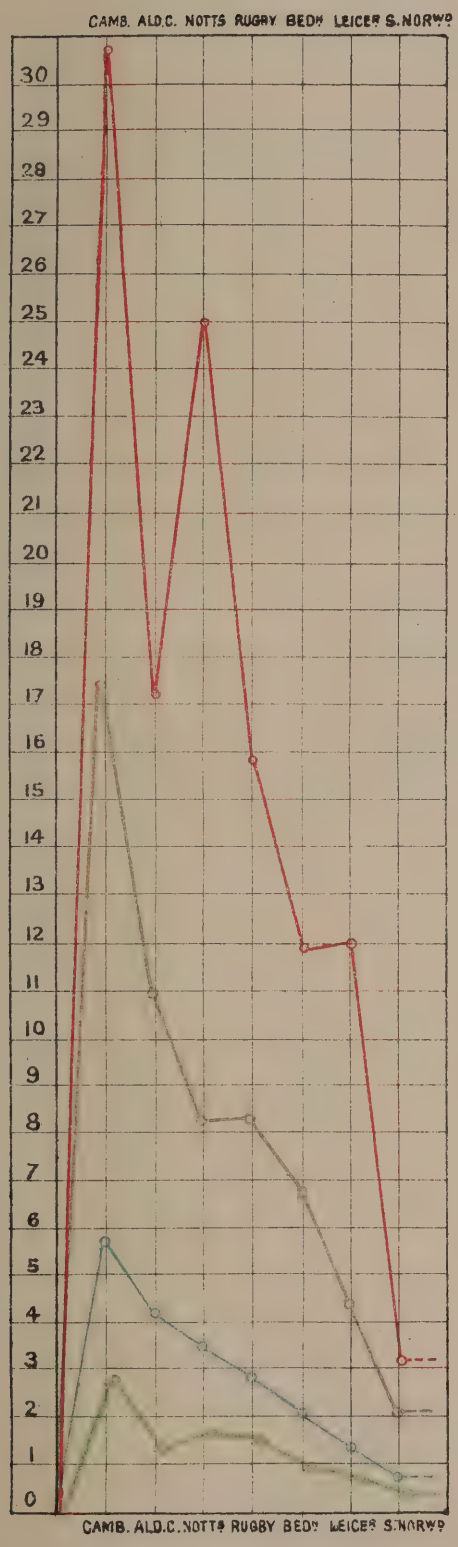


Diagram to indicate approximately the relative proportions of

(A) Albuminoid Nitrogen.

(B) Total Organic Nitrogen.

(C) Total Nitrogen

(D) Oxidizable matter as measured by the 4 hours "Oxygen absorbed" test at 26·7°C. (80°F.)

which are treated per acre by the seven Sewage Farms undermentioned, on the assumption, for purposes of comparison, that each acre of irrigable area is under sewage all the year round.

The Farms are

1 CAMBRIDGE
2 ALDERSHOT CAMP.
3 NOTTINGHAM
4 RUGBY
5 CROYDON (Beddington)
6 LEICESTER
7 SOUTH NORWOOD

Notes.

1 *Those curves are arrived at by multiplying the average figures obtained in the analysis of the Hourly Samples of Sewage by the respective volumes treated per acre of irrigable area.*

2 *The figures in the vertical line of this diagram indicate merely relative, not absolute, amounts, i.e. not parts per 100.000.*

3332.2.03.

Weller & Graham Ltd Litho. London.

ALDERSHOT CAMP SEWAGE FARM.

Chemical Report.

1. Situation of farm.—Ashvale, close to Camp.
2. Total acreage of farm.—138·5 acres.
3. Total irrigable area.—120·5 acres.
4. Average area irrigated at one time.—About 40 acres.
5. Population draining to farm.—20,000.
6. Population per acre irrigated.—166.
7. Gallons of sewage per head per day.—50.
8. Dry weather flow of sewage per 24 hours.—1,000,000 gallons.
9. Gallons of sewage (exclusive of storm water) treated per acre per 24 hours —24,900.
10. Gallons of sewage treated per acre per 24 hours, on the assumption that each acre of irrigable area is under sewage all the time—8,300.
11. Character of the sewage.—Purely domestic.
12. Method of treatment.—Screening, settling tanks and land filtration.
13. General character of the soil and subsoil.—Sand.
14. Separate or combined sewerage system.—Separate.
15. The final effluent is discharged into.—River Blackwater.
16. Number of years farm in operation before 1900.—36 years.

ALDERSHOT CAMP SEWAGE FARM.

This farm dates from the year 1864, so that it is about the same age as the farms at Rugby, Beddington and South Norwood.

The total irrigable area of land is 120·5 acres, about *one-third* of this being sewaged at a time. The whole of the land is under crop at one time or another.

The average depth of the drains is given by Mr. Kershaw as 3 feet 3 inches, the land being too level to allow of drainage at a greater depth.

For the same reason the sewage can only be treated *once*, i.e. an effluent cannot be picked up at the lower end of one field and sent over a second one. *The effluents are entirely percolation effluents, from one treatment of the sewage*, like those at Nottingham and Cambridge.

Soil and Subsoil.

The surface soil and subsoil are sand, a little gravel occurring in the subsoil in parts. The following table gives the mechanical composition of average samples of these :—

Name of Fraction.	Surface Soil per Cent.			Sub-soil per Cent.		
	Not Ignited.	Ignited.	Difference.	Not Ignited.	Ignited.	Difference.
"Gravel" (above 8·0 m.m. diameter) - -	—	—	—	—	—	—
Fine "Gravel" (above 2·0 m.m. diameter) -	6·29	5·94	0·35	1·52	1·50	0·02
Coarse "Sand" (above 1·0 m.m. diameter) -	0·69	0·62	0·07	0·90	0·87	0·03
Coarse "Sand" (above 0·5 m.m. diameter)-	0·60	0·53	0·07	0·45	0·44	0·01
Medium "Sand" (above 0·25 m.m. diameter)	1·35	1·27	0·08	1·29	1·28	0·01
"Sand" (0·25 to 0·05 m.m.) - - -	82·67	81·76	0·91	80·13	79·50	0·63
"Silt" (0·05 to 0·01 m.m.) - - -	4·19	2·93	1·26	6·58	6·21	0·37
"Dust" (from 0·01 m.m. downwards, which settles from water in 24 hours) - -	3·12	2·05	1·07	5·52	5·13	0·39
"Clay" (*i.e.* the still finer residue, precipitated from water by dilute nitric acid) -	0·35	0·24	0·11	2·62	2·28	0·34
Loss on ignition (separate determination) -	—	3·60	—	—	1·80	—
	99·26	98·94	3·92	99·01	99·01	1·80
Real specific gravity of soil dried at 110° C.	2·526	—	—	2·579	—	—
Apparent specific gravity - - -	1·467	—	—	1·469	—	—
Number of particles in 1 gramme of the ignited soil or subsoil (approx.) - -	154,373,990			1,142,111,850		
Number of particles in 1 c.c. of the ignited soil or subsoil (approx.) - - -	226,466,640			1,677,742,900		
Weight of water retained by 100 grammes of the soil when fully drained - - -	29·2	—	—	29·7	—	—
Parts per 100,000.						
Lime dissolved by water in 24 hours - -	0·004	—	—	0·005	—	—
Lime dissolved by water saturated with carbonic acid, in 48 hours - - -	0·030	—	—	0·018	—	—

For a discussion of the figures given in this table, see section upon Soils : page 275.

Volume Treated per Acre, etc.

The dry weather flow of sewage is about 1,000,000 gallons per 24 hours; and, for the reasons given by Mr. Kershaw in his Report,‡ this quantity is remarkably constant. The average population draining to the farm is 20,000, which gives 166 persons per acre irrigated, and a flow of 50 gallons per head.

While the farm was under observation for the Commission the water supply was about 43 gallons per head,* which leaves about 7 gallons for subsoil leakage into the sewers, etc.

In winter during rainfall there is some subsoil water on the farm itself, but not at other times.

The average area irrigated at one time is about 40 acres, one acre treating 24,900 gallons. But again assuming, *for purposes of comparison*, that the entire irrigable area is under sewage continuously, *then each acre treats* 8,300 *gallons per* 24 *hours all the year round.*

Nature of Sewage (*Diagram No.* 5).

This is purely domestic and it is, of course, very strong. It has, however, such a short distance to travel before it reaches the farm that the screening of the grosser solids from it is very easy; and hence, although it is only allowed one hour's stay in the settling tanks, the amount of suspended solids in the sewage as run on to the land is not excessive.

Thirteen samples in all were analysed, viz.: 10 chance samples and three sets of hourly samples drawn in equal quantities every hour during the 24 hours of the day (Nos. 460, 462 and 464). Sample No. 48, an exceedingly strong sample of *crude* sewage, may be left out of account in making any comparisons or calculations, seeing that the treatment on the farm is a treatment of *screened and settled* sewage, the sludge being dug in separately. All the other samples drawn were screened and settled. The whole of the samples were of course alkaline in reaction and the chance ones had a more or less strong "sewage" smell, the odour of the sets of hourly samples being more that of urine.

The temperature of the chance samples drawn in March varied between 7·2° and 8·3° C. (45° and 47° F.), and of the others drawn in April, May, June and July, between 9·4° and 25·6° C. (49° and 78° F.†). These temperatures were taken, as a rule, where the sewage leaves the tanks.

A reference to the Tables of Analysis and Curves will show that the hourly samples were distinctly weaker than the chance ones, the latter having been nearly all drawn in the forenoon when the sewage was at its strongest. And, besides this, Aldershot Camp is essentially a place where hourly samples drawn in equal quantities per hour—and not according to rate of flow—will give a weaker average than the reality, for the following reasons:—

(1.) Because, being a barrack town, the variations in the flow of sewage at different times of the day will be great, and at the same time of regular recurrence.

(2.) Because comparatively little water gets into the sewers at night to minimise the effects of what has been described under (1).

For purposes of approximate calculation, therefore, the averages of both chance and hourly samples will be given separately, the true figures most probably lying somewhere between the two.

---

* Since then we understand that the supply has been reduced to 25 gallons per head.

† This last abnormally high temperature figure was that of a sewage taken from a carrier in the month of July.

‡ Part IV. Engineering and Practical Report.

The more important analytical results may be summarised as follows :—

(*Note.*—All these samples were screened and settled.)

	Average
Total Nitrogen—(*a*) 9 chance samples (12·45 to 24·89) - - -	17·6
(*b*) 3 sets of hourly samples (12·31 to 14·24) - - -	13·3
Ammoniacal Nitrogen—(*a*) 9 chance samples (8·26 to 16·94) -	12·30
(*b*) 3 sets of hourly samples (7·60 to 8·21) - - - -	7·87
Total Organic Nitrogen—(*a*) 9 chance samples (3·39 to 9·10) -	5·35
(*b*) 3 sets of hourly samples (4·25 to 6·18) - - - -	5·06
Albuminoid Nitrogen—(*a*) 9 chance samples (2·05 to 3·63) - -	2·77
(*b*) 3 sets of hourly samples (1·54 to 1·69) - - - -	1·62
"*Oxygen absorbed*" *in* 4 *hours* at 26·7° C. (80° F.)—	
(*a*) 9 chance samples (20·68 to 38·47) - - - - -	25·94
(*b*) 3 sets of hourly samples (19·54 to 22·40)- - - -	20·79
Chlorine—(*a*) 9 chance samples (8·90 (?) to 13·98) - - -	11·38
(*b*) 3 sets of hourly samples (11·36 to 19·78) - - -	14·98
Chlorine in water supply—(1·2* to 1·7) - - - - say,	1·5
Chlorine in Subsoil Water - - - - - - -	1·2
Ratio of Ammoniacal Nitrogen to Chlorine—3 sets of hourly samples (1 : 1·49 to 1 : 2·41) - - - - - -	1 : 1·89
Ratio of Ammoniacal Nitrogen to Chlorine, after deducting the Chlorine of the water supply—3 sets of hourly samples (1 : 1·30 to 1 : 2·23) - - - - - - - -	1 : 1·70
Solids in Suspension—3 sets of hourly samples (32·0 to 39·8) -	36·6
† *Solids in Suspension by Centrifuge* (*Volumes*)—3 sets of hourly samples (148 to 216) - - - - - - - -	173
Ratio of Solids in Suspension to Centrifuge Solids - 3 sets of hourly samples. { 1 : 3·9, 1 : 4·8, 1 : 5·4 } -	1 : 4·7
Cellulose, still containing fat, 3 sets of hourly samples (9·00 to 12·68) (One extraction with dilute alkali and one with dilute acid)	10·79
Ratios of Cellulose containing fat to Suspended Solids 3 sets of hourly samples. { 1 : 3·5, 1 : 3·6, 1 : 3·1 } -	1 : 3·4
Cellulose, 3 sets of hourly samples (3·88 to 4·00) - - - - (extraction with alkali, acid and ether)	3·95
Ratios of Cellulose to Suspended Solids - - 3 sets of hourly samples. { 1 : 9·7, 1 : 8·1, 1 : 11·2 } -	1 : 9·7

Taking the 9 chance samples of screened and settled sewage, they were not by any means even in composition, Nos. 50, 54, 81 and 302 being distinctly stronger than the others as regards "oxygen obsorbed," while Nos. 50, 81, and 303 were the strongest as regards total nitrogen. No. 54 showed the largest amount of organic nitrogen, and No. 302 was remarkable for the excessive volume of solids that it contained (553 volumes as determined by the centrifuge).

The 3 sets of hourly samples were in every respect, excepting in the matter of chlorine, very similar to one another. Why there should have been so much chlorine in No. 464 it is impossible to say (Mr. Kershaw suggests that it may have come from chloride of lime).

The hourly samples contained small amounts of nitrate when analysed, a proof of the infiltration of some subsoil water into the sewers.

---

* There are two sources of water supply.

† Four of the chance samples gave centrifuge solids (118 to 553), average 311·0.

A reference to the Curves brings out the following further points.

The sewage being a very strongly ammoniacal one, the curves for *total nitrogen* and *ammoniacal nitrogen* necessarily follow one another closely; but there is no resemblance between these two on the one hand, and the curves for total organic and albuminoid nitrogen on the other (excepting between ammoniacal and albuminoid nitrogen in the hourly samples).

The relation between the *albuminoid* and the *total organic nitrogen* varied considerably, but, on a rough average, the amount of total organic nitrogen was about twice that of the albuminoid in the chance samples and about three times in the hourly samples.

In the 5 cases where the organic nitrogen was determined by both Kjeldahl methods, the results agreed fairly well.

Excepting in the 3 sets of hourly samples, the "*oxygen-absorbed*" curve bears no resemblance to the curve for total nitrogen, but it is to a slight extent similar in character to that for organic nitrogen.

The average ratio between organic nitrogen and "oxygen absorbed" in the 9 chance samples of sewage is 1 : 4·8, while in the 3 sets of hourly samples it is 1 : 4·1. Those ratios agree very fairly with the corresponding ones from the Beddington and South Norwood sewages, both of which are also domestic sewages, though weaker.

The average ratio between albuminoid nitrogen and "oxygen absorbed" in the 9 chance samples of sewage is 1 : 9·9, and in the three sets of hourly samples 1 : 12·9, the ratio in both cases being fairly constant throughout, especially in the hourly samples.

In the chance, but not in the hourly samples, the *chlorine* curve is of the same type as those for ammoniacal and total nitrogen, the agreement being fairly good. The chlorine in the sewer subsoil water must of course be a disturbing element here.

The *suspended solids* in those chance samples which were tested by the centrifuge varied enormously in amount In the 3 sets of hourly samples the suspended solids were fairly constant in themselves but not in the ratios which they bore to the centrifuge solids (average = 1 : 4·7). The centrifuge, therefore, did not give a very good idea of the suspended solids in this (screened and settled) sewage; some further determinations would be desirable. It will be seen, however, that the above ratio is a lower one than that given by any of the other sewages that were centrifugalised.

The ratios between the *suspended solids* on the one hand and the *cellulose* of those solids on the other, in the hourly samples, do not agree very well (the average is 9·7 : 1). More determinations would be necessary here.

Effluents from Old Land and General Effluents (*Diagram No.* 6).

As will be seen later, an opportunity occurred of observing the degree of purification effected by perfectly new and *hitherto unsewaged land at* this farm. The effluents from the new land will be considered separately, but one must bear in mind here that those *general* effluents which were drawn at times when the new land—as well as part of the old—was under sewage, were to some extent made up of effluent from this new land; and as the latter took a long time to get "ripe," the above general effluents were therefore necessarily not of such good quality as would otherwise have been the case. The samples of general effluent which would thus contain new land effluent were Nos. 89, 246, 310, 390, 396 and 398, while the other general effluents examined were Nos. 52, 53 and 56. These three last mentioned were drawn before the new land came into operation.

As already stated, *all of these were Filtration Effluents which had passed once through the soil.* Five of them (Nos. 49, 51, 52, 56 and 247) were drawn from unchalked land, and the remainder from chalked.

Seventeen Final and General Effluents were analysed fully, and nine of these seventeen were further examined, either fully or partially, after jointing or incubation. The effluents were drawn in March, April and June, 1900; April, June, July and October, 1901.

The temperature of those 17 effluents, *when drawn*, varied between 5·6° and 15° C. (42° and 59° F.), not a very great range; the two with the lowest temperature were taken in the beginning of April, and the one with the highest in July. It will be remembered that the drains at Aldershot Camp Farm are of necessity only 3′ 3″ deep on the average. (Cf. Temperature Curves in Engineering Report.)

The following short table shows some of the more important average analytical results from the examination of 16 to 18 effluents, details being given in the Table of Analysis and Curves :—

	Average.
Total Nitrogen (3·69 to 8·99) - - - - - -	6·0
Ammoniacal Nitrogen (0·91 to 4·98) - - - - -	1·85
Albuminoid Nitrogen (0·12 to 0·47) - - - - -	0·26
Nitric and Nitrous Nitrogen together (0·0 to 5·97) - -	3·21
"Oxygen absorbed" from permanganate at 26·7° C. (80° F.) *in* 4 *hours* (1·02 to 5·68) - - - - - -	2·72
Incubator Test (as judged by smell) - - - - -	89 °/₀ passed. (18 samples tested.)

All the effluents were more or less yellow or brown in colour (but those tested for this point were colourless or light yellow when filtered), and they contained *very decided* amounts of red-brown flocculent suspended solids, *i.e.*, fragments of weed coated with red oxide of iron, washed from the drains. Those solids are, however, extremely light. Thus, in two subsequent comparative estimations, (*a*) 50·2 (centrifuge) volumes per 100,000 corresponded to only 2·33 parts by weight, of which 1·26 parts were volatile; and (*b*) 81·6 (centrifuge) volumes corresponded to 2·09 parts by weight, of which 1·11 parts were volatile. Excepting No. 56 (a bad sample, drawn in part from land which was undrained and not levelled), and No. 90,* both of which had a putrefactive smell, and No. 247, which had a suspicious smell but was nevertheless a good effluent, all the samples had either a clean earthy or a fishy-earthy smell when they came to be analysed; a few of them, however, were noted as having more or less of a sewage smell when drawn. One or two had an alkaline reaction, but the general reaction was acid from dissolved carbonic acid derived from the oxidation of the carbonaceous matter of the sewage; they all became alkaline upon boiling. I have noted with regard to No. 89 (and this is no doubt true of the others also) that the colour of the liquid was in part due to dissolved organic matter. These effluents contained only a moderate amount of lime† in solution, but much sulphate.

As will be seen from the Analytical Tables and Curves, the effluents were decidedly stronger in every respect in summer than in autumn and winter, and the nitration was evidently rather more than proportionately greater in the warm months.

In only six of the 17 samples was there more than 2 c.c. per litre of *dissolved oxygen* left when the effluent came to be analysed; in four the oxygen varied from 1 to 2 c.c.; and in the remaining seven it was either *nil* or less than 1 c.c. Being percolation effluents, these were probably not fully aerated when drawn, and, further, the copper chloride oxygen process would give too low readings with such coloured effluents (the first seven were boiled out). But, even allowing for this, and for the fact of the rate of absorption of dissolved oxygen being largely a question of temperature, these figures indicate that there was still a little fermentable organic matter left in some of the effluents. The latter contained, however, such a large excess of nitrate that, with the exception of No. 56, already referred to (and No. 90), they all remained perfectly sweet upon incubation (compare Incubation results, Table A). In connection with this, it will be noted here that the smell of these effluents, when drawn, was no criterion of their keeping property.

The amounts of *dissolved carbonic acid* were very great (up to 118 c.c. free carbon dioxide per litre), this being of course what one would expect in the case of a land percolation effluent from a strong sewage. The figures for the dissolved

* No. 90 was not analysed.

† The proportion of lime in the Aldershot Camp soil and subsoil was very small as compared with that found at the other farms (Cf. Section on Soils).

nitrogen were also very high (up to 20·7 c.c. per litre), some of the figures indicating super-saturation with nitrogen.

The *Ammoniacal Nitrogen* in 17 effluents varied between 0·91 and 4·98 parts, the average being 1·85. It thus constituted rather less than one-third of the total nitrogen present.

The *Albuminoid Nitrogen* in 17 samples of effluent varied between 0·12 and 0·47, the average being 0·26. It must, however, not be forgotten, with regard to this item, that some of the albuminoid nitrogen (as well as of the total organic nitrogen) came from the flocculent suspended solids in the effluents; and, more especially, that we are here dealing with effluents from a very strong sewage. (Cf. remarks upon Standards for Effluents in *Conclusions: page* 303 *et seq.*).

The figures for "*oxygen-absorbed*" in four hours varied between 1·02 and 5·68*, the average for 16 effluents being 2·72.

The Average Ratio of Albuminoid Nitrogen to "oxygen absorbed" from permanganate in 4 hours, after allowing for nitrite, was in 17 effluents 1 : 11, the extremes being 1 : 5 and 1 : 19. This ratio was a very uneven one, as can be seen by a reference to the Curves.

Upon *Jointing or Incubation*, all of the 17 samples excepting No. 56 kept sweet as judged by smell, though five of them would have been condemned by Mr. Scudder's permanganate test. The latter condemned the duplicate jointed sample of No. 49, although it still had a large reserve of nitrate; in the case of No. 247, also condemned by this test, the incubated duplicate had an exceptional reserve of nitrate; but in No. 398, likewise condemned, the reserve of nitrate on incubation had fallen to near zero. It would seem, therefore, that Mr. Scudder's test, while generally applicable to these Aldershot Camp effluents, is occasionally rather too stringent.† The incubation test, as judged by smell, proved itself a safer guide.

The Total Nitrogen in those 17 effluents was high, varying as it did between 3·69 in No. 49 and 8·99 in No. 305, the average being 6·0. This high figure is of course to a considerable extent due to the fact that many of the samples were drawn in summer when the evaporation must have been great. A glance at the curves will show that, of this total nitrogen, about two-thirds was nitric nitrogen.

Leaving the strong summer samples out of account, it is perhaps worth while to compare for a moment the spring and autumn samples of effluent at Aldershot Camp with those at Rugby. In the former case the total nitrogen in the effluents relatively to that in the sewage was greater, and the ratio of nitric nitrogen to total nitrogen was greater also. Without attempting to push the argument too far (for there are many factors here, *e.g.*, differences in the strengths of the sewage, subsoil water, evaporation, taking up of nitrogen by plants, etc.), this looks as if the system of treatment adopted at Rugby resulted in a greater loss of *gaseous* nitrogen than in the other case.

The apparently large quantity of *Total Organic Nitrogen* found in some of the samples was striking, and at first one was inclined to attribute this to the flocculent suspended solids present.‡ But, although this is no doubt correct to some extent, there is considerable uncertainty here, for later investigations showed that there may possibly have been some appreciable errors in determining the organic nitrogen by the method of Kjeldahl *with* reduction. Thus, the relatively small quantity of lime in the Aldershot Camp effluents was afterwards found to be insufficient to prevent loss of nitrous nitrogen from nitrite when boiling down some of them (in order to get rid of ammonia) in the estimation of nitrate; again, possible small quantities of nitric nitrogen may have been lost in this way also, though this is unlikely and

* *Note.* This very high figure (5·68) was given by the bad sample No. 56; the next highest figure was 4·09, and the next to that 3·81.

† In the earlier Aldershot Camp effluents the amount of nitrous nitrogen remaining after incubation was not noted, and its "oxygen" equivalent could not be deducted from the "oxygen absorbed" figure found. When, therefore, the figures left any doubt as to whether or not an effluent withstood incubation, as judged by Mr. Scudder's reduction in permanganate used up, I have given that sample the benefit of the doubt and marked it +. As a matter of fact this only occurred in Nos. 51 and 55 jointed.

‡ Portions of these flocculent solids, collected from a number of residues in sample bottles, mixed, and dried at 100° C., yielded 1·33 per cent. of nitrogen.

has been more or less disproved later; and, lastly, the nitric acid in some of the more highly nitrated effluents may have been slightly under-estimated, through too much liquid having been taken for the analysis. For these reasons the determination of the organic nitrogen by Kjeldahl *with* reduction cannot be altogether relied upon here, and neither the figures nor the curve of those figures is given. (This question is discussed in the Report upon "Methods of Chemical Analysis," where it is pointed out how such errors can be avoided in future.) On the other hand, the determination of the organic nitrogen in those effluents by the Kjeldahl method *without* reduction was altogether unsatisfactory, the results coming out very low, no doubt for the reasons given under "Methods of Analysis;" the figures of this determination are to be found in the Tables of Analysis, but the curve is not given in Diagram No. 6.

Most of the effluents contained some *nitrite* (in amounts varying between 0·02 and 0·24 nitrous nitrogen), and the quantity of *nitrate* was large all through, and—excepting in the case of No. 56—sufficient to preserve the sample upon incubation. Leaving out of account sample No. 90, which went putrid upon incubation and was not analysed, the *Nitric plus Nitrous Nitrogens* (together) in 17 effluents varied between 1·61 and 5·97, the average being 3·4—a high figure.

The ratio of oxidized to unoxidized nitrogen (taking the unoxidized =1) varied in 17 samples between 0·3 and 2·6, the average being 1·4. The safety limit of ratio lies somewhere between 0·3 and 0·6, that is to say, one sample in which the ratio was 0·3 went bad on incubation, whilst all from 0·6 upwards kept good on incubation as judged by smell.

The ratio of oxidised to albuminoid nitrogen (taking the albuminoid = 1) varied in the 17 effluents between 3·6 and 39·4, the average being 17·5,—a high ratio. The safety limit ratio evidently lies above 3·6, *i.e.*, the sample with the figure 3·6 went bad on incubation while a sample with a ratio of 4·0 kept good. To make a definite statement on this point, however, would necessitate the examination of some further samples just on the boundary line.

The *chlorine* curve in the effluents was markedly higher in summer and also in autumn than in spring. It does not bear much resemblance to any other curve. Although it approximates less to a straight line than many of the other effluent chlorine curves, still it does show to a certain degree the "equalisation" of the liquid in its passage through the soil, partly—no doubt—from the effects of rain and of subsoil water.

The "*oxygen absorbed*" curve bears a moderate resemblance to those for the albuminoid nitrogen and the total nitrogen. As a rule, when the "oxygen-absorbed" curve rises, the nitrate curve falls, and *vice versa*, but not always.

The *suspended solids*, as determined by the centrifuge, varied in six cases between 27 and 63 volumes per 100,000, and in two others went up to 133 and 196 volumes.* No corresponding gravimetric estimations were made in those samples, but in the other two (already quoted) the ratio of suspended solids, determined gravimetrically, to centrifuge solids was 1 : 22 and 1 : 39. Even allowing for the fact of these being so light and flocculent, it is clear that some of the effluents contained more of them than was desirable.

A short study of Table A may be of interest; this table gives some of the figures of the analyses of nine effluents, which were examined in duplicate (*a*) before and (*b*) after jointing or incubation. In the table no particular importance can be attached (1) to the increase or decrease of the albuminoid nitrogen, for that is merely a part of the total organic nitrogen. But if the amounts of nitric + nitrous nitrogen on the one hand, and of ammoniacal nitrogen on the other be looked at, it will be seen that out of the nine samples there is only in three of them any appreciable decrease of nitric + nitrous nitrogen after jointing or incubation (and in one of these, No. 55, the decrease is doubtful), and, moreover, that decrease is quite small relatively to the total oxidized nitrogen present; further, in only one case out of seven (No. 319), is there any appreciable increase in the ammoniacal nitrogen. (The incubated samples

* Compare Mr. Kershaw's Notes on Samples, *e.g.* with reference to Sample No. 53.

had of course the benefit of any dissolved oxygen originally present, in addition to the nitrate; this oxygen was always used up, or practically so.) Again, in the two cases where there was a distinct diminution of nitrate upon incubation, the figures for "oxygen absorbed" (four hours) in the original samples were higher than in the other cases. Those three tests (diminution of nitrate on incubation, increase of ammonia on incubation, and "oxygen absorbed" in original sample) therefore confirm and strengthen one another here. These results show that though the above Aldershot Camp Farm effluents gave high figures for albuminoid nitrogen and "oxygen absorbed," not very much of the organic matter which was left in them was of a fermentable character. (Cf. remarks on the absorption of dissolved oxygen in the Summary of Conclusions).

TABLE A.—ALDERSHOT CAMP FARM. OLD LAND AND GENERAL EFFLUENTS, EFFECT OF INCUBATION ON.

Parts per 100,000 by Weight.	No. 49, Jointed.			No. 52, Jointed.			No. 55, Jointed.			No. 246.			No. 247, Jointed.		
	Original Sample.	Incubated Sample.	Increase or Decrease.	Original Sample.	Incubated Sample.	Increase or Decrease.	Original Sample.	Incubated Sample.	Increase or Decrease.	Original Sample.	Incubated Sample.	Increase or Decrease.	Original Sample.	Incubated Sample.	Increase or Decrease.
Nitric plus Nitrous Nitrogen	2·25	2·29	+ 0·04	2·56	2·59	+ 0·03	2·12	1·37 (?)	− 0·75 (?)	3·63	3·13	− 0·50	5·07	5·27	+ 0·20
Ammoniacal " -	1·19	1·19	0·00	1·27	—	—	1·96	1·83	− 0·13	2·08	2·09	+0·01	1·32	1·40	+ 0·08
Albuminoid " -	0·41	0·33	− 0·08	0·15	0·14	− 0·01	0·17	0·13	− 0·04	0·32	0·30	− 0·02	0·13	0·12	− 0·01
Oxygen absorbed from Permanganate in 4 hours at 26·7° C. (80° F.) - -	2·00	2·06	+ 0·06	2·56	1·85	− 0·71	2·53	2·44	− 0·09	2·76	—	—	1·75	—	—
Incubation by Scudder's Test	+	—	—	+	+	—	+	+	—	+	—	—	−	+	—
Incubation by Smell - -	+ (?)	+	—	+	+	—	+	+	—	+	+	—	+	+	—

	No. 304.			No. 310.			No. 319.			No. 398.			—		
Nitric plus Nitrous Nitrogen	5·91*	6·32	+ 0·43 (?)	4·32	5·35 (?)	+ 1·02 (?)	4·20	3·16	− 1·04	3·21	3·36	+ 0·15	—	—	—
Ammoniacal " -	1·07	—	—	1·35	1·39	+ 0·04	3·17	3·68	+0·51	1·32	—	—	—	—	—
Albuminoid " -	0·15	—	—	0·19	0·20	+ 0·01	0·36	0·30	− 0·06	0·12	—	—	—	—	—
Oxygen absorbed from Permanganate in 4 hours at 26·7° C. (80° F.) - -	1·87	—	—	1·69	—	—	4·09	—	—	1·02	2·00	+ 0·98	—	—	—
Incubation by Scudder's Test	+	—	—	+	—	—	+	+	—	−	—	—	—	—	—
Incubation by Smell - -	+ *Probably rather low.	+	—	+	+	—	+	—	—	+	+	—	—	—	—

In conclusion.—The Aldershot Camp farm treats on a sandy soil and subsoil a medium volume of a strong sewage per acre of irrigable area, and at the same time a large quantity of organic matter (compare diagrams Nos. 3 and 4). The effluents produced may be summed up as being highly nitrated, and, although some or most of them still contained appreciable amounts of organic matter, not very much of that was of a fermentable character, under laboratory conditions of experiment; further, the nitrate present was much more than sufficient to keep them sweet. They had in them more flocculent suspended solids—washed out of the drain pipes—than was desirable. Would it be possible to settle these out or to screen them before the effluent passes into the brook? Although, therefore, these effluents cannot be reckoned among effluents of the highest class, they are no doubt as good as can be obtained from a sandy soil, which has to treat a fairly large volume of strong sewage by one percolation through a depth of three feet. The approximate number of particles per gramme of ignited soil is 154,373,990, and per gramme of subsoil 1,142,111,850; or the approximate numbers in unit weights of the ignited soil and subsoil (taking those at Nottingham as 100 in each case) are:—Soil, 19; subsoil, 394; in unit volumes the numbers are 19 and 326.* The relative calculated *internal* filtering area, per unit of surface, down to the drains is approximately the same as at Nottingham, but it is differently divided between surface soil and subsoil in the two cases. The rate of filtration through such a very fine sandy subsoil must be rather slow. (Compare section dealing with Soils, and also *Conclusions* to Chemical Report.)

Percentage purification as calculated on the albuminoid nitrogen and "oxygen absorbed" in four hours:—

(1) *Albuminoid Nitrogen.*

		Average
9 chance samples of screened and settled sewage gave	(2·05 to 3·63)	2·77
3 sets of 24 hourly samples " " "	(1·54 to 1·69)	1·62
17 Old land and general effluents - - -	(0·12 to 0·47)	0·26

The percentage purification therefore was

(*a*) On the chance samples - - - - - -	93·9%
(*b*) On the hourly samples - - - - - -	84·0%

(2) *Oxygen absorbed.*

9 chance samples of screened and settled sewage gave	(20·68 to 38·47)	25·94
3 sets of 24 hourly samples " " "	(19·54 to 22·40)	20·79
16 old land and general effluents - - - -	(1·02 to 5·68)	2·72

Percentage purification:

(*a*) On the chance samples - - - - -	89·5%
(*b*) On the hourly samples - - - - - -	86·9%

Comparison of the Total Nitrogen in the Sewages and Final Effluents.

The average total nitrogen in 9 chance samples of sewage was	(12·45 to 24·89)	17·6
" " 3 sets of hourly samples	(12·31 to 14·24)	13·3
" " 17 old land and general effluents	(3·69 to 8·99)	6·0

Disregarding the subsoil water on the one hand (Mr. Kershaw states in his Report that there is not much of this) and loss of liquid by evaporation on the other, this shows that fully one-third of the original nitrogen of the sewage finds its way to the brook. It is a pity that this large quantity of manure in an inoffensive form should be lost.

* Cf. page 292, last paragraph.

Effluents from New Land "A." (Diagram No. 7.)

This new land (A) was brought into operation in May, 1900, and we had thus an opportunity of keeping it under observation for the Commission from the very beginning, and of drawing a few samples in four separate series, viz., in May and June, 1900; July 1901; October, 1901; and January, 1902.

In May, 1902, Mr. Henderson, the farm bailiff, wrote to Mr. Kershaw the following particulars:—

"The new land was laid out for sewage in 1900, and sown with rye grass. "Started sewaging in May, 1900. Sewage taken off after about 14 days and the "land rolled. Sewage put on again immediately after the rolling. Since then, "sewaged after each crop was cut, about the same as the old land." While being laid out, the land received 20 tons of chalk per acre.*

The first set of samples (Nos. 82, 83, 84, 85, 87 and 88) drawn in May and June, 1900, were—as might have been expected—uniformly bad, very little nitrification going on. Reference should be made here to Mr. Kershaw's Notes† with regard to these samples, which show that the land was still far from being consolidated, and that holes forming in it allowed some of the sewage to run direct to the drains.

Any detailed description of the chemical analyses of these samples would be superfluous, as a glance at the curves and figures is almost sufficient to indicate their character. In temperature they hardly varied at all, the limits being 11·4° and 12·8° C. (52·5° to 55° F.); this is not surprising, seeing that they were all drawn within a period of ten days. They were *deep brown* in colour (this colour being due mainly to organic matter, though there was a little iron present), had either a sewage or seaweed smell when analysed, and—with the exception of No. 86—contained but a little red brown flocculent matter. There was very little lime, and only a moderate quantity of sulphate in solution, together with appreciable amounts of ferrous and ferric iron (mostly in suspension). It is noteworthy that the effluents were nearly all strongly acid from carbonic acid (becoming alkaline on boiling), the quantity of free carbon dioxide which could be boiled out being excessive (up to 162·7 c.c. per litre). This proves, of course, that a vigorous oxidation of the carbonaceous matter of the sewage had been going on from the very commencement, though the high "oxygen absorbed" curve shows that there was still much left in the liquid. Since there was hardly any nitrification—hardly any nitrate on analysis at all events—the total nitrogen was made up almost entirely of ammoniacal and organic nitrogen. Not one of the samples withstood incubation.

In the earlier samples the determination of organic nitrogen came out better by the Kjeldahl method *without* reduction than by the other.

The second set of samples (Nos. 321, 323, 324 and 325), all of which were examined before and after incubation, were drawn between July 17th and 24th, 1901, *i.e.* when the land was—as regards sewage—a year old. In temperature they showed an absolutely constant figure, viz., 15° C. (59° F.); and in practically all other respects they were similar to the first set of samples. A reference to Mr. Kershaw's Notes on Samples† will show that here again the conditions were not favourable to the land; he explains how it came about that No. 323 contained so much sediment, and how Nos. 324 and 325 were rendered more impure than would otherwise have been the case by the influx of a little surface-treated sewage. Excepting No. 323, all four samples were destitute of nitrate when they came to be analysed, and the other figures of the partial analyses were bad (see curves). Further, not one of them withstood the incubation test.

The third set consisted of one sample only (No. 404), which was drawn in October, 1901, after a heavy rainfall, and examined in duplicate. It, too, was

* This amounts to less than ½ lb. of chalk per square yard of soil; or, taking the weights of soil and subsoil together down to the drains, the added chalk would be only about 0·02 % of the whole by weight.

† Part IV. Engineering and Practical Report.

bad, though it showed some signs of improvement upon those preceding it. By this time—indeed, before this time—a considerable quantity of weed had evidently collected in the drain pipes and was being washed down by the effluent. The temperature of this sample was 11·1° C (52° F.).

The fourth and last set consisted of two effluents (Nos. 461 and 463), drawn in January, 1902, *i.e.*, 20 months after the commencement. As will be seen by a reference to the figures and curves, these were of a totally different character to all the others, being effluents of a high class, with a considerable quantity per litre of dissolved oxygen and over six parts per 100,000 of nitric nitrogen (*no* nitrous nitrogen). No. 463 contained much more brown flocculent sediment than No. 461; the gravimetric estimation of solids, though only approximate, showed, however, that this flocculent matter (apparently weed) was very light. The temperature of the second of these effluents was extremely low for a percolation effluent, even in January, viz., 1·7° C. (35° F.), but it had no doubt run some distance in the open.

The above results are of very great interest, as showing how long a time was required—from one cause or another—to bring this plot of absolutely sandy soil into a fit state for purifying sewage. This slow ripening of the sandy soil may have been due, among other things, to the great ammoniacal strength of the sewage; to the dose of sewage having been at first too large; to the small quantity of lime in the soil; and to the ground not having been properly consolidated.

Before concluding the subject, I should like to call attention to the following point:—If we leave out of account sample No. 323, which was only partially analysed (it was very strong, and but little effluent was running at the time) and No. 324, which was only incubated and not analysed, and take the other ten samples of the 1st, 2nd and 3rd series, we find that the *average total nitrogen* in these is 4·21 parts (2·87 to 9·31, all excepting No. 325 being under 5·0). This is a lower figure than that for the average total nitrogen in the old land effluents where nitrification was active. Now the average total nitrogen in the three sets of hourly sewage samples was 13·3, and, for the reasons already given, this is probably rather under the true average. The above figures, therefore, show that though the effluents from the new land "A" were still bad at the time they were drawn, more than two-thirds of the total nitrogen of the sewage had been removed, and yet no nitrate was present in the effluents.

The diminution in the "oxygen absorbed" figures was relatively rather less, viz., from about 20 parts to 8, a diminution of about three-fifths (the actual "oxygen absorbed" figures were 6·91 to 9·64, and, in the case of No. 88, 17·16).

Effluents from New Land "B." (*Diagram No.* 8.)

This portion of the new land "B" adjoined A," but was not ready for sewage until a year later, *i.e.* in June 1901; only one set of samples was taken from it, in June and July of that year. These having been drawn immediately after the sewage was applied to the ground, should be comparable with the first set of samples drawn from "A." Their numbers were 307, 309. 312, 313, 317 and 318, and all of them excepting No. 312 were drawn in duplicate, the second samples being examined after incubation.

Having all been taken within a period of 17 days, the temperature of these effluents was very constant, varying only between 12·2° and 14·4° C. (54° and 58° F.), with a gradual rise all the time.

Like the first set of effluents from "A," these were all deep brown in colour, and with but little suspended matter. Excepting No. 312, they all had a clean or sea-weed smell when they came to be analysed, and were strongly acid from dissolved carbonic acid, becoming just alkaline upon boiling. So far, therefore, the remarks made under "A" apply to these effluents also. But, curiously enough, with the exception of No. 312, they kept sweet upon incubation for 5 days, although the duplicates of the three last (Nos. 313, 317, and 318), which were incubated for longer periods, went bad. The longer incubated duplicate of No. 307 kept sweet, while that of 309 was on the border line.

This shows, what I have already observed in other cases, that five days incubation at 26·7° C. (80° F.) is not sufficient to prove *definitely* that a sample will absolutely withstand putrefaction. There was no dissolved oxygen and but little nitrate present in these effluents, and though they were of distinctly better quality all round than the early samples from "A," one would not have expected from their analyses that they would have shown even the keeping power that they did. Can the large amount of dissolved carbonic acid present have exercised a retarding effect upon the action of the putrefactive germs?

It is hardly necessary to enter into a minute examination of the figures and curves, enough having been already said to indicate the nature of the effluents, but one or two points may be referred to:—

1. The *chlorine* curve is here almost a straight line, differing in this respect from the chlorine curves of the other Aldershot Camp farm effluents.

2. The *albuminoid nitrogen* is relatively high as compared with the *total organic nitrogen* (this in half-purified effluents). The two methods for the determination of organic nitrogen do not agree well, the method without reduction being evidently unsuitable here.

3. With reference to sample No. 309, Mr. Kershaw has noted that moles had been at work during the time that the field was dry (under hay). No. 312, already referred to as a specially bad sample, was drawn during a very heavy rainfall, this causing some sewage to flow direct into the effluent chamber. When No. 313 was taken, the ground had not yet recovered from the effects of this rain. Nos. 317 and 318 show some improvement upon the preceding samples, though why No. 317 should have contained so much suspended solid (relatively) is not clear.

Thus those effluents, while distinctly better than the early effluents from New Land "A," were still not at all good, oxidation not having gone far enough. That they should have been better than the others was probably due —if one may hazard a conjecture—to the better state of consolidation of the ground when the sewage came to be applied.

The *total nitrogen* in the five effluents analysed was again *very low*, varying from 2·14 to 3·53, the average being 2·9. When this is compared with the 13·3 parts in the hourly samples of sewage, it is seen that—roughly speaking—78 per cent. of the nitrogen has disappeared (Cf. remarks under "A."). This of course takes no account of rainfall on the one hand, or of evaporation on the other.

Street Washings.

Two samples from Aldershot Camp were examined, viz., No. 311, being Street Washings from Surface Water ditch, drawn on July 2nd, 1901, after two days' heavy rainfall; at the time of drawing, Mr. Kershaw noted that this ditch was flowing at the rate of ten million gallons per 24 hours. The sample was brown and turbid, though it had only a slight brown tinge when filtered; it contained a great deal of sand and also some brownish suspended matter. The analysis showed as much as ·49 part of albuminoid nitrogen, 1·05 parts total organic nitrogen, and 8·93 parts "oxygen absorbed" in four hours. Though this had a clean smell when analysed, no doubt because of some nitrate which it contained, it turned black and putrid upon incubation.

No. 314, Street Washings and Roof water from Aldershot Camp, drawn July 3rd, 1901, after three days' rain, was muddy from considerable suspended matter, with grit in addition. Though the aggregate organic matter was less than No. 311 (·34 albuminoid nitrogen; ·64 total organic nitrogen; and 3·46 "oxygen absorbed"), there was no nitrate; the sample was smelling slightly when analysed and became black upon incubation.

Subsoil water.

One analysis was made of a well water, sample No. 60, which was the only sample that we could get to represent subsoil water; the well was far enough from the farm to be in no danger of contamination. This water was fairly pure, though containing too much albuminoid nitrogen for a drinking water, while there was also present a large amount of oxidisable organic matter, as measured by the "oxygen absorbed" test. The absence of nitrate, however, and the comparatively small proportion of chlorine point to this oxidisable matter being of a vegetable character. The small quantity of dissolved oxygen present is noteworthy. Unfortunately there was no incubation of a duplicate sample, to measure how far this oxygen decreased under those conditions. A Kjeldahl estimation *without reduction* was made, with apparently a good result as regards the organic nitrogen. For drinking water the other method (*with reduction*) is inapplicable, for the reasons already given.

Samples from the river Blackwater, drawn both above and below the Farm Effluent outfall. (*Diagram No.* 9.)

In the Engineering Report (Part IV.) Mr. Kershaw says:—

"The river Blackwater, into which the effluent finally passes, is a small, muddy, sluggish stream. The ratio of effluent to river water is about 1 : 6 approximately. The normal volume of the river is increased considerably by any rainfall."

Seven samples were examined (Nos. 57, 58, 59, 315, 316, 326 and 327), five of them in duplicate after jointing or incubation, so that twelve analyses in all were made. Nos. 57, 315, and 326 were drawn above the farm effluent outfall and the other four below it. While only one of the samples went bad upon incubation, it is quite obvious from a study of the analytical figures and curves that this stream was not in a satisfactory condition. In July, 1901, it was practically an effluent; and not a particularly good one. It must have been very much polluted above the effluent outfall, the worst sample of all (No. 326) having been taken above the latter.

The differences in the figures given by the samples drawn in March, 1900, when the temperature was low and the brook evidently full, and in July, 1901, when the temperature was high and the brook low, are very striking.

Samples 57, 58 and 59 are comparable, and a glance at the curves shows distinctly—though not very markedly—the influx of effluent. No. 59 duplicate (brook water containing effluent) used up all its dissolved oxygen and half of its nitrate on being jointed and kept, which was not altogether satisfactory. Mr. Kershaw, however, states (see his Notes on Samples*) that cattle had apparently been in the stream between the points at which Nos. 58 and 59 were drawn, some time previously to his taking this sample, which would of course deteriorate the water.

Samples 315 and 316 are also comparable. When they came to be analysed, two days after being drawn in July, No. 315 contained only 1 c.c. of oxygen per litre and No. 316 none. The effluent carried with it sufficient nitrate to raise the nitric nitrogen in the stream from 0·04 to 0·84 parts, and on the whole it appeared at this time to have a purifying effect chemically on the river water.

With regard to No. 326, drawn above outfall, and No. 327, drawn below it, the former has been already referred to as a very bad sample, which went putrid upon incubation; Mr. Kershaw notes that it was a turbid sample drawn during rain. Here the river was certainly benefited chemically by the effluent.

Just a few words may be added with regard to the figures of analyses and curves:—

1. The relatively large volumes of suspended solids (for a river water), as measured by the centrifuge, are noteworthy.

---

* Part IV. Engineering and Practical Report.

2. In the summer samples the dissolved oxygen had gone down to zero or nearly zero in every case when the analysis came to be made; this is of course very unsatisfactory.

3. The variations in the chlorine curve, following as it does the curve for total nitrogen, are very striking.

4. The organic nitrogen is approximately twice the albuminoid nitrogen. There is not a very good agreement between the two methods for determining the organic nitrogen, and neither of them is wholly satisfactory.

5. The curves for albuminoid nitrogen and "oxygen absorbed" follow one another fairly well.

6. With inflow of effluent into the stream the nitrate curve rises regularly.

7. Mr. Scudder's incubator test was much more stringent than the incubator test as judged by smell; at the same time the smell was of doubtful value and difficult to characterise in No. 58 and to some extent also in No. 59.*

The river Blackwater was thus not in a satisfactory state chemically at the time of our observations, more especially during summer, but this was due to polluting matter entering it above the farm and not to the farm itself. In some cases, at all events, the Aldershot Camp farm effluent must have exercised an oxydizing effect on the organic matter already present in the water. Reference has already been made to the rather considerable bulk of fine flocculent weed from the drain pipes which is carried into the stream along with the effluent. Apart from the manurial loss of nitrate, etc., in an effluent discharging into a stream, the rapid choking up of the latter by the vegetable growth which this fosters is a point to which attention has been called by other writers, *e.g.*, Mr. Roechling. It seems a great pity that such a highly nitrated effluent as that from the Aldershot Camp Farm cannot be utilised, by being carried to such a distance as would allow of its distribution by irrigation over other land.

**Note.*—In Samples Nos. 57, 58, 59 and 59 (Jointed), there was no nitrous nitrogen before incubation. The nitrous nitrogen after incubation was not noted, so it is assumed—(what in all probability is the case)—that there was none then also.

ALDERSHOT CAMP SEWAGE FARM.

TABLES OF ANALYSIS.

INDEX.

	PAGE.
Hourly Sewage Samples, Nos. 460, 462, 464	25
Sewages, Old Land and General Effluents, Nos. 48, 49, 50, 51	26
,, ,, Nos. 52, 53, 54, 55, 56	27
,, ,, Nos. 89, 90, 245, 246	28
,, ,, Nos. 247, 302, 304	29
,, ,, Nos. 303, 305, 308, 310	30
,, ,, Nos. 310, 319, 390, 396, 398	31
Sewage and Effluents from New Land "A," Nos. 81, 82, 83	32
,, ,, Nos. 84, 85, 86, 87, 88	33
,, ,, Nos. 320, 321, 322	34
,, ,, Nos. 322, 323, 324, 325	35
,, ,, Nos. 404, 461, 463	36
Sewage and Effluents from New Land "B," Nos. 306, 307, 309, 312	38
,, ,, Nos. 313, 317, 318	39
Street Washings, Nos. 311, 314	40
Well (*i.e.* Subsoil) Water, No. 60	41
River Water above and below Effluent outfall (including one effluent):—Nos. 56, 57, 58, 59	41
,, , ,, Nos. 315, 316, 326, 327	42

ALDERSHOT CAMP FARM, 1902.

Sets of Hourly Sewage Samples drawn in Equal Quantities per Hour.

No. of Sample	No. 460.	462.	464.
Nature of Sample	Screened and Settled Sewage, 24 hours' sample.	Screened and Settled Sewage, 24 hours' sample.	Screened and Settled Sewage, 24 hours' sample.
Rainfall* while sample was being drawn.	0·01″	0·00″	0·00″
Drawn	From Monday, 27th January, 1902, 12 noon, to Tuesday, 28th January, 11 a.m.	From Tuesday, 28th January, 1902, 12 noon, to Wednesday, 29th January, 11 a.m	From Wednesday, 29th January, 1902, 12 noon, to Thursday, 30th January, 11 a.m.
Analysed	29th January, 1902.	30th January, 1902.	31st January, 1902.
Parts per 100,000, *by weight.*			
Ammoniacal nitrogen (by distillation)	7·81	7·60	8·21
Albuminoid nitrogen	1·62	1·54	1·69
Nitrous ,,	0·02	0·03	0·01
Nitric ,,	0·23	0·43	0·25
Total nitrogen by Kjeldahl, *with* reduction.	12·31	14·24	13·24
Blank	(0·54 in 9·53)	(0·54 in 10·94)	(0·54 in 10·21)
"X" nitrogen	2·63	4·64	3·08
Organic nitrogen by Kjeldahl, *with* reduction.	4·25	6·18	4·77
Oxygen absorbed from permanganate at 26·7° C. (80° F). ; *at once.*	3·42	3·88	2·75
,, ,, ,, *after four hours*	20·43	22·40	19·54
Chlorine	13·80	11·36	19·54 (a) Feb. 14, 20·06 (b)
Total solids (gravimetrically)	124·2 { 64·0 Volatile, 60·2 Non-vol.	125·2 { 67·0 Volatile, 58·2 Non-vol.	134·8 { 60·6 Volatile, 74·2 Non-vol.
Solids in suspension ,,	37·8 { 28·8 Volatile, 9·0 Non-vol.	32·0 { 25·8 Volatile, 6·2 Non-vol.	39·8 { 26·2 Volatile, 13·6 Non-vol.
Solids in solution ,,	86·4 { 35·2 Volatile, 51·2 Non.vol.	93·2 { 41·2 Volatile, 52·0 Non-vol.	95·0 { 34·4 Volatile, 60·6 Non-vol.
Cellulose still containing fat (by alkali and acid alone) (a).	10·68	*9·00	12·68
Cellulose (by alkali, acid and ether) (b)	3·88	*3·96	4·00
Grit { from (a)	4·84*	*3·28	3·52
Grit { from (b)	4·44*	—	3·56
Parts per 100,000 *by volume.*			
Solids by centrifuge	148† (3 minutes)	155 (3 minutes)	216·0 (3 minutes)
Remarks	This sample was turbid, with—for a sewage—a moderate amount of brown suspended matter and deposit. Doubtful faint urine smell. Alkaline.	Turbid, with a moderate amount of brown sediment. Distinct urine smell. Alkaline.	This sample had much the same appearance as No. 462, but there was rather more suspended matter in it. Distinct urine smell. Alkaline.

* There was heavy rain early on Monday morning before the sampling was begun.

* This difference (between 4·84 and 4·44) may possibly be due to the balance having been slightly disturbed.

† 3 minutes' revolution.

* Those two estimations of cellulose and one of grit made with one and the same quantity of sewage.

ALDERSHOT CAMP SEWAGE FARM, 1900.

Sewages with Old Land and General Effluents.

No. of Sample	No. 48	49	49	50	51
Nature of Sample	Crude Sewage.	Effluent from Arable Unchalked Land, corresponding to Sewage No. 48.	Large Duplicate.	Settled Sewage.	Effluent, corresponding to Sewage No. 50, from Rye Grass Land unchalked.
Drawn	Monday, 12th March, 1900, 11 a.m.	Monday, 12th March 1900, 3.15 p.m.	——	Wednesday, 14th March 1900, 11 a.m.	Wednesday, 14th March 1900 3.15 p.m.
Temperature of sample	83° C. (47° F.)	6·7° C. (44° F.)	——	7·2° C. (45° F.)	6·7° C. (44° F.)
Temperature of air	——	——	——	——	——
If jointed or incubated	——	——	Jointed, 13th March.	——	——
Analysed	13th March 1900	13th March 1900.	9th April 1900.	16th March 1900.	15th March 1900.
Parts per 100,000 *by weight.*					
Ammoniacal nitrogen (a) by direct Nesslerization.	17·95 approx.	1·09	1·52	17·29	2·22
Ammoniacal nitrogen (b) by distillation	22·33	1·19	1·19	16·94	1·66
Albuminoid nitrogen	7·76	0·41	0·33	3·33	0·21
Nitrous "	Trace.	0·07	0·02	Possible trace.	0·24
Nitric "	Not done.	2·18	2·27	Not done.	2·01
Total nitrogen by Kjeldahl, *with* reduction (after nitrite correction).	36·15	3·69	3·49	24·89	4·36
Blank	(0·23 in 13·35)	(0·22 in 5·54)	(0·23 in 5·28)	(0·23 in 9·23)	(0·22 in 6·37)
Correction for nitrite	None.	+0·03	+0·01	None.	+0·12
"X" nitrogen	6·06	——	——	4·62	——
Organic nitrogen by Kjeldahl, *with* reduction.	13·82	——	——	7·95	——
Organic nitrogen by Kjeldahl, *without* reduction:					
(a) Taking ammonia by direct Nesslerization.	——	0·28	None (−0·45)	7·42	None (−0·20)
(b) Taking ammonia by distillation	——	0·18	None (−0·12)	7·77	0·36
Oxygen absorbed from permanganate at 26·7°C. (80° F.); *at once.*	13·90	0·55	0·60	13·87	0·65
" " " *after four hours*	51·02	2·00	2·06	38·47	2·16
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once*	——	0·47 (Six days.)	0·88	——	0·60
" " " *after four hours*	——	1·64 (Six days.)	1·93	——	2·31
Smell after incubation	——	Earthy (?).	Quite sweet; Earthy	——	Earthy.
Chlorine	——	7·90	——	11·75	9·34
Gases: Parts per 1,000 *by volume.*					
Carbon dioxide (free)	——	79·50	84·07	——	111·77
Oxygen (boiled out)	——	5·30	0·17	——	2·11
Nitrogen	——	17·36	17·08	——	19·44
Remarks	Copious brown sediment. Strong sewage smell. Alkaline.	Decidedly yellow and opalescent, with very considerable brownish flocculent matter. Clean fishy - earthy smell. Acid from carbonic acid; alkaline on boiling. A moderate amount of lime in solution, but a considerable quantity of sulphate. The large amount of dissolved carbonic acid is noteworthy.	On opening this bottle, it was seen that a few drops of water had been forced through the mercury joint, and there was a small bubble of gas at top of bottle (say, 0·2 to 0·3 c.c.). I think there was a very slight inward suction on opening the bottle. A minute bubble of air (quite negligable) got into gas apparatus from filling tube.	Considerable brown deposit. Sewage smell. Alkaline.	Opalescent and yellowish-brown. A *very* considerable amount of flocculent matter. Clean, earthy smell. Acid from carbonic acid. Moderate amount of lime in solution, but a large quantity of sulphate. *Note.* — The above carbonic acid is mostly from organic matter.

NOTE.—The following + corrections have been made in the figures for nitric nitrogen, to allow for loss of nitrite when boiling down for nitrate: + ·01 in Nos. 53, 56, 89, 246 and 304; + ·03 in No. 305; + ·08 in No. 319; and + ·09 in No. 55.

ALDERSHOT CAMP SEWAGE FARM, 1900.

Sewage, with Old Land and General Effluents.

52	52	53	54	55	55	56
General Effluent off unchalked Rye Grass Land.	Duplicate.	General Effluent off chalked Land.	Settled Sewage.	Effluent off Rye Grass Land (unchalked.)	Duplicate.	General Effluent from low unchalked Land.
Monday, 19th March 1900, 11.15 a.m.	—	Monday, 19th March 1900, 11.30 a.m.	Wednesday, 21st March 1900, 1 p.m.	Wednesday, 21st March 1900, 4 p.m.	—	Tuesday, 27th March 1900 12.15 noon.
6·7° C. (44° F.)	—	7·2° C. (45° F.)	7·8° C. (46° F.)	6·1° C. (43° F.)	—	7·8° C. (46° F.)
—	—	—	—	—	—	—
—	Jointed 20th March.	—	—	—	Jointed 22nd March.	—
20th March 1900.	24th April 1900.	21st March 1900.	23rd March 1900.	22nd March 1900.	25th April 1900.	28th March 1900.
1·35	1·39	2·34	—	1·98	2·06	—
1·27	1·25	2·42	8·26	1·96	1·83	4·98
0·15	0·14	0·47	3·63	0·17	0·13	0·45
0·04	None.	0·09	0·03	0·23	0·20	0·09
2·52	2·59	1·80	Not done.	1·89	1·15 (?) (must be wrong).	1·52
3·93	3·93	5·16	17·39	4·25	4·18	7·71
(0·23 in 5·91)	(0·19 in 5·89)	(0·23 in 7·65)	(0·23 in 12·84)	(0·22 in 6·20)	(0·19 in 6·02)	(0·22 in 11·36)
+0·02	None.	+0·05	+0·02	+0·13	+0·06	+0·04
—	—	—	5·47	—	—	—
—	—	—	9·10	—	—	—
0·03	0·03	0·47	—	—	None (−0·08)	—
0·11	0·11	0·39	—	—	0·15	0·47
0·48	0·52	0·85	5·67	0·72	0·62	0·95
Lost.	1·85	3·09	31·37	2·53	2·44	5·68
0·37 } Six days	0·32	0·59	—	0·37	0·47	0 97
2·03 } Six days	1·77	2·43	—	2·33	2·14	3·76
Sweet.	Quite sweet.	Earthy.	—	Either sweet or nearly so.	Quite sweet.	Distinctly putrefactive.
8·16	—	8·98	8·90 (?)	9·74	—	10·26
84·33	89·94	87·72	—	114·84	118·22 (probably a trace too low.)	81·44
4·84	0·38	0·52	—	1·80	0·42	*3·10
17·00	16·86	17·39	—	19·14	20·67	18·05
Reddish - brown and opalescent liquid, with an appreciable amount of red-brown flocculent matter. Clean earthy smell. Strong acid reaction (from carbonic acid, doubtless). Only a moderate amount of lime, but a good deal of sulphate in solution.	Some water had oozed out through the mercury joint and there was a tiny bubble of gas at top of bottle. Sediment had aggregated. No smell. Beyond losing its oxygen, this sample has undergone no change.	0·3 inches of snow had fallen in the 15 hours preceding drawing of sample. In appearance this sample was about the same as No. 52, but the brown flocculent matter had aggregated more. Acid, but less so than before. A moderate amount of lime in solution, but a considerable amount of sulphate. In estimating the gases, this sample did not boil out so quickly as the previous ones.	For a sewage, a moderate amount of light brown deposit. Faint sewage smell. Alkaline.	Turbid, with too large a quantity of red - brown flocculent matter; decidedly acid till boiled; then alkaline. Clean smell. Moderate amount of lime, but a large quantity of sulphate in solution. The stopper of sample bottle may have been a little loose when it arrived. The gases boiled out well and quickly.	The sediment had aggregated, and some of it stuck on the bottom. This would *slightly* affect the sample for analysis. Fishy smell. There was quite a large quantity of water on the top of the mercury joint, but only about 0·5 c.c. of gas inside the bottle.	Part of this effluent came off land which was neither drained nor levelled, and it was a very bad one. Turbid, with very considerable brown flocculent matter. Slight, but distinct putrefactive odour. Slightly acid. Very considerable amount of lime, and a great deal of sulphate in solution.

In boiling out, the gas came off much more slowly than in previous sample.

**Note.*—The presence of this large amount of oxygen in a bad effluent must be due to the low temperature.

ALDERSHOT CAMP SEWAGE FARM, 1900–1901.

Sewage, with Old Land and General Effluents.

No. of Sample	No. 89	90	245	246	246
Nature of Sample	General Effluent from Old Land (chalked).	Effluent from Old Land (Chalked).	Settled Sewage.	General Effluent from Old (chalked) Land (slight smell when drawn).	Small Duplicate.
Drawn	Wednesday, 6th June 1900, 2.30 p.m.	Thursday, 7th June 1900, 3.15 p.m.	Monday, 1st April 1901, 2 p.m.	Monday, 1st April 1901, 2.15 p.m.	—
Temperature of sample	12·2° C. (54° F.)	17·2° C. (63° F.)	9·4° C. (49° F.)	5·6° C. (42° F.)	—
Temperature of air	16·7° C. (62° F.)	14·4° C. (58° F.)	10·6° C. (51° F.)	10·6° C. (51° F.)	—
If jointed or incubated	—	—	—	—	Jointed and incubated, 2nd April.
Analysed	8th June 1900.	12th June 1900.	2nd April 1901.	2nd April 1901.	12th April 1901
Parts per 100,000, *by weight.*					
Ammoniacal Nitrogen: (a) by direct Nesslerization	1·81	—	—	—	—
(b) by distillation	1·83	—	12·54	2·08	2·09
Albuminoid nitrogen	0·37	—	2·22	0·32	0·30
Nitrous nitrogen	0·06	—	None.	0·06	None.
Nitric	1·81	—	Not done.	3·57	3·13
Total nitrogen, by Kjeldahl, *with* reduction, after correction for nitrite in No. 89.	4·17	—	16·83	April 3 5·95 May 12 6·19	—
Blank	(0·19 in 6·20)	—	(0·19 in 7·06)	(0·19 in 9·91) (0·33 in 5·38)	—
Correction for nitrite	+0·03	—	—	—	—
"X" nitrogen	—	—	2·07	—	—
Organic nitrogen by Kjeldahl, *with* reduction.	—	—	4·29	—	—
Organic nitrogen by Kjeldahl, *without* reduction: (a) Taking ammonia by direct Nesslerization.	0·07	—	—	—	—
(b) Taking ammonia by distillation	0·05	—	—	—	—
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once.*	0·81	—	7·18	0·73	0·54
" " " *after four hours*	3·81	—	22·09	2·76	—
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80 F.); *at once*	0·87	—	—	0·61 } 9 days	—
" " " *after four hours*	3·76	—	—	2·47 } 9 days	—
Smell after incubation	Sweet.	—	—	Sweet, no nitrite.	Fishy smell.
Chlorine	9·92	—	13·98	11·20	—
Parts per 100,000 *by volume.*					
Solids by centrifuge	—	—	—	—	—
Gases: parts per 1,000 *by volume.*					
Carbon dioxide (free)	100·04	—	—	—	—
Oxygen (boiled out)	0·12	—	—	—	—
Oxygen (by cuprous chloride): When sample was analysed	—	—	—	1·0 or less { two observers.	—
Nitrogen	15·43	—	—	—	—
Remarks	Medium brown in colour, with considerable red-brown matter in suspension. Distinctly acid, but alkaline after boiling. Clean fishy-earthy smell. Lime in solution was considerable, sulphate very considerable. A little ferric iron in solution and a fair amount in suspension. The colour of the liquid was evidently due in part to organic matter.	When opened, this was *putrid.* The temperature had been very high for some days (up to 88° F. in the shade yesterday.)	This *liquid* was very turbid and yellow, but with *relatively* not much sediment. The filtered liquid still remained very turbid and coloured Sewage smell, not very strong. Alkaline.	This was a brown liquid, but fairly clear when the sediment had settled. There was a considerable amount of light brown sediment with weed, which could not be broken up. Fishy smell. Alkaline.	After incubation this was a fairly clear yellow liquid, with considerable amount of grey-brown sediment (aggregated). Fishy smell. Alkaline.

ALDERSHOT CAMP SEWAGE FARM, 1900–1901.

Sewage, with Old Land and General Effluents.

247	247	247	302	304	304
EFFLUENT from Rye Grass on ld Land (unchalked). o smell when drawn.	SMALL DUPLICATE.	LARGE DUPLICATE.	SETTLED SEWAGE.	EFFLUENT from Old Land (chalked).	SMALL DUPLICATE.
Ionday, 1st April 1901, 3.0 p.m.	—	—	Wednesday, 19th June 1901, 11.5 a.m.	Wednesday, 19th June 1901, 12.30 noon.	—
5·6° C. (42° F.)	—	—	20° C. (68° F.)	12·2° C. (54° F.)	—
10·0° C. (50° F.)	—	—	18·9° C. (66° F.)	21·1° C. (70° F.)	—
—	Jointed and incubated, 2nd April.	Jointed, 2nd April.	—	—	Jointed and incubated, 20th June.
2nd April 1901.	11th April 1901.	4th June 1901.	20th June 1901.	20th June 1901.	27th June 1901.
Turbid.	—	Turbid.	—	Turbid.	—
1·32	—	1·40	11·05	1·07	—
0·13	—	0·12	2·86	0·15	—
0·01	Trace.	0·01	None.	0·09	0·03
5·06	5·27	5·55	Not done.	(?) 5·82 { Probably rather low.	6·29
7·01	—	6·54 (?)	16·72	(a) 8·40 (b) 8·64 { June 28th.	—
(0·16 in 10·34)	—	(0·24 in 10·77)	(0·24 in 12·99)	{ (0·24 in 13·05) 0·24 in 12·76 }	—
—	—	—	—	—	—
—	—	—	2·81	?	—
—	—	—	5·67	?	—
—	—	—	—	—	—
0·40 { rather turbid	—	None (?)	4·48	None.	—
0·37	—	0·31	6·25	0·41	—
1·75	—	1·63	27·98	1·87	—
0·41 } 9 days.	—	0·31 } Six	—	0·31	—
1·66 }	—	1·63 } days.	—	1·81	—
weet. Nitrous nitrogen = 0·005 approx.	No smell.	Sweet. Trace of nitrous nitrogen, probably less than 0·01.	—	Sweet. Nitrous nitrogen = 0·04 approx.	Clean smell.
10·86	—	—	10·62	11·52	—
—	—	—	553·0 (One minute.)	37·0 (One minute.)	—
—	—	—	—	—	—
—	—	—	—	—	—
3·3 { Two observers.	less than 0·5	None.	—	About 2·5.	None.
—	—	—	—	—	—
palescent, with a very considerable amount of green weed. Clear and colourless when filtered. Acid from carbonic acid, but alkaline on boiling, Suspicious smell; Musty smell; Sewage smell 3 observers.)	The liquid was now clear and brown, with aggregated buff-coloured sediment. No smell.	The liquid was fairly clear, with a large amount of buff-coloured sediment. Acid till boiled, then alkaline. Earthy smell.	This sewage was slightly brown, but yellow on filtering, with considerable dark brown sediment and a good many floating grass seeds. Sewage smell. Alkaline.	This was rather turbid and brown, with a moderate amount of buff brown sediment. Very faintly acid, but alkaline on boiling. Clean but rather strong smell.	After incubation the liquid was fairly clear, with buff sediment. Clean smell, and not so strong as in the original sample.

ALDERSHOT CAMP SEWAGE FARM, 1901.

Sewage, with old Land and General Effluents.

No. of Sample	No. 303.	305	308	310
Nature of Sample	Settled Sewage.	Effluent from Old Land *(Chalked) corresponding to Sewage No 303.	Final Effluent from Old Land (Chalked) (contained some Sewage weed).	General Effluent.
Drawn	Wednesday, 19th June 1901, 11.30 a.m.	Wednesday, 19th June 1901, 12.45 noon.	Tuesday, 25th June 1901, 11.45 am.	Thursday, 27th June 1901, 10.45 a.m.
Temperature of sample	17·8° C. (64° F.)	12·2° C. (54° F.)	13·3° C. (56° F.)	12·8° C. (55 F.)
Temperature of air	20·0° C. (68° F.)	21·1° C. (70° F.)	20·0° C. (68° F.)	21·1° C. (70° F.)
If jointed or incubated	——	——	——	——
Analysed	20th June 1901.	20th June 1901.	26th June 1901.	28th June 1901.
Parts per 100,000 *by weight.*				
Ammoniacal nitrogen :				
(a) by direct Nesslerization	——	——	Turbid.	Turbid.
(b) by distillation	13·71	2·52	1·39	1·35
Albuminoid nitrogen	2·30	0·47	0·19	0·19
Nitrous	None.	0·15	0·05	0·03
Nitric	Not done.	5·82	5·05	4·29
Total nitrogen by Kjeldahl, *with* reduction (no correction for nitrite).	18·66	8·99	7·76	7·48
Blank	(0·34 in 15·58)	(†0·50 in 15·18)	(0·24 in 11·48)	(0·24 in 11·07)
"X" nitrogen	2·65	——	——	——
Organic nitrogen by Kjeldahl, *with* reduction.	4·95	——	——	——
Organic nitrogen by Kjeldahl, *without* reduction :				
(b) Taking ammonia by distillation	4·41	None (–0·08)	None (–0·08)	None (–0·19)
Oxygen absorbed from permanganate at 26·7° C (80° F) ; *at once.*	7·17	1·11	0·53	0·35
" " " *after four hours*	21·39	3·71	2·52	1·69
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C (80° F) ; *at once*	——	0·81	0·41	0·21
" " " *after four hours*	——	3·80	2·50	1·57
Smell after incubation	——	Earthy, about 0·03 nitrous nitrogen	Sweet, about 0·05 nitrous nitrogen.	Earthy, with only trace of nitrite.
Chlorine	13·12	13·74	13·92	11·86
Parts per 100,000 *by volume.*				
Solids by centrifuge	228·0 (1½ minutes.)	133·0 (1½ minutes.)	196·0 (one minute.)	63·0
Gases : Parts per 1,000 *by volume.*				
Oxygen (by cuprous chloride) : When sample was analysed	——	None.	About 0·8	None.
Remarks	Very turbid dark grey - brown liquid, with a large amount of dark sediment. Strong sewage smell. Alkaline.	Brownish and rather turbid liquid, with considerable amount of light brown sediment (apparently vegetable). Fishy smell. Alkaline.	This was slightly turbid, with much buff and reddish-brown flocculent sediment. Nearly colourless when filtered. Acid from carbonic acid, but alkaline on boiling. Clean smell.	This sample was rather turbid, with a moderate amount of buff-coloured sediment. Faintly acid till boiled; then alkaline. Strong but clean smell.

*Note.—From No. 304, onwards, all the effluents came from chalked land.

† Double amounts of acid and zinc were used in this Kjeldahl.

ALDERSHOT CAMP SEWAGE FARM, 1901

Sewage, with old Land and General Effluents.

310 Small Duplicate.	319 Final Effluent from Old Land.	319 Small Duplicate.	390 General Effluent.	396 General Effluent.	398 General Effluent.	398 Small Duplicate.
—	Monday, 15th July, 1901, 10·15 a.m. 15·0° C. (59° F.) 21·7° C. (71° F.)	—	Monday, 14th Oct., 1901, 12.30 noon. 12·2° C. (54° F.) 13·9° C. (57° F.)	Tuesday, 15th Oct. 1901, 11.10 a.m. 12·2° C. (54° F.) 14·4° C. (58° F.)	Wednesday, 16th Oct. 1901, 11 a.m. 12·2° C. (54° F.) 11·7° C. (53° F.)	—
Jointed and incubated, 28th June. 15th July 1901.	— 16th July 1901.	Jointed and incubated, 16th July. 7th Aug. 1901.	— 16th Oct. 1901.	— 16th Oct. 1901.	— 17th Oct. 1901.	Jointed and incubated, 17th Oct. 18th Nov. 1901.
—	—	—	—	—	—	—
1·39	3·17	3·68	0·99	0·91	1·32	—
0·20	0·36	0·30	0·12	0·12	0·12	—
Trace.	0·20	0·05	0·02	0·03	0·03	3·36 { 5 c.c. Reduced after boiling.
5·35?	4·00	3·11	3·07	2·80	3·18	
Note. This nitrate estimation is doubtful. The ammonia came off badly, in dribbles. It is a curious case.	7·88	—	5·14	4·83	5·46	—
	(0·30 in 11·71)	—	(0·30 in 7·81)	(0·34 in 7·43)	(0·34 in 8·36)	—
	—	—	—	—	—	—
	—	—	—	—	—	—
—	None (—0·01)	—	—	—	—	—
0·46	0·95	1·14	0·53	0·41	0·55	0·73
—	4·09	—	2·29	1·59	1·02	2·00
— —	0·68 } six 3·74 } days	— —	0·51 } 12 1·94 } days	0·33 } six 1·24 } days	0·59 1·84	— —
Seaweed smell.	Sweet, but strong. No nitrite.	Clean smell.	Sweet, trace of nitrite.	Sweet, trace of nitrite.	Sweet, trace of nitrite.	Clean.
	11·56	—	12·30	11·96	12·66	—
—	27·0 (One minute.)	—	44·0 (3 minutes)	46·0 (3 minutes.)	52·0 (3 minutes.)	—
—	None.	—	1·2	1·75 approx. (two observers.)	0·75 (two observers.)	—
After incubation this liquid was clear, with a yellow tinge and seaweed smell. Much light-brown sediment.	Turbid and brown, but light yellow when filtered. Slight greyish-brown sediment. Seaweed smell. Faintly alkaline.	After incubation the liquid had a brownish tinge. Small amount of sediment. Clean smell.	Slightly yellow in colour, with considerable light brown suspended matter. Acid from carbonic acid; alkaline on boiling. Slight earthy smell.	This liquid was slightly turbid and with a small amount of light brown, almost yellow, sediment. Acid in the cold; alkaline on boiling No smell.	This sample was brown and slightly turbid with a fair amount of brown sediment. Rather fishy smell. Acid in the cold; alkaline on boiling.	After incubation, clear but rather deep yellow brown liquid. Some light brown flocculent sediment. Clean smell. Alkaline.

ALDERSHOT CAMP SEWAGE FARM, 1900–1.

Sewage, with Effluents from New Land "A."

No. of Sample	No. 81	82	82	83
Nature of Sample	Settled Sewage from Marlboro' lines.	Effluent from New Land A (chalked).	Duplicate Sample.	Effluent from same source as No. 82.
Drawn	Monday 28th May 1900, 11.45 a.m.	Monday 28th May 1900, 3 p.m.	—	Tuesday 29th May 1900, 3.15 p.m.
Temperature of sample	14·7° C. (58·5° F.)	11·4 C. (52·5° F.)	—	11·7° C. (53° F.)
Temperature of air	19·4° C. (67° F.)	18·9° C. (66° F.)	—	17·2° C. (63° F.)
If jointed or incubated	—	—	Jointed.	—
Analysed	29th May 1900.	29th May 1900.	Opened 17th July 1900.	30th May 1900.
Parts per 100,000, *by weight.*				
Ammoniacal nitrogen: (a) by direct Nesslerization	12·85	2·47	—	2·31
(b) by distillation	14·38	2·41	—	2·20
Albuminoid nitrogen	3·29	0·64	—	0·37
Nitrous "	None.	0·09	—	0·06
Nitric "	Not done.	0·45 Not a satisfactory estimation.	—	0·39
Total nitrogen by Kjeldahl, *with* reduction (after nitrite correction).	19·91	3·22	—	3·04
Blank	(0·19 in 14·64)	(0·19 in 4·81)	—	(0·19 in 4·56)
Correction for nitrite	None.	+0·04	—	+0·03
"X" nitrogen	2·24	?	—	0·02
Organic nitrogen by Kjeldahl, *with* reduction.	5·53	?	—	0·42
Organic nitrogen by Kjeldahl, *without* reduction: (a) Taking ammonia by direct Nesslerization.	Lost.	0·60	—	0·65
(b) Taking ammonia by distillation	—	—	—	0·76
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once*	7·01	1·50	—	1·37
" " " *after four hours*	29·88	7·48	—	7·90
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once*	Not done.	1·63 Seven days.	—	1·91 Six days.
" " " *after four hours*	"	5·65		lost
Smell after incubation	"	Sewage smell.	—	Smell of sulphide.
Chlorine	12·27	—	—	—
Gases: parts per 1,000 *by volume.*				
Carbon dioxide (free)	—	140·05	—	153·67
Oxygen (boiled out)	—	0·11	—	0·14
Nitrogen	—	15·91	—	15·37
Remarks	There was a considerable brown sediment in this sample. Strong sewage smell. Very alkaline.	Very dark brown and turbid, with but little suspended matter. It had a mixed sewage and iron smell, I think. Decidedly acid, becoming slightly alkaline on boiling. Only a little lime and not very much sulphate in solution. A fair amount of ferric iron (mostly in suspension), and evidently some ferrous iron also.	— When opened, this smelt strongly of ammonium sulphide. Not analysed.	Very dark brown and opalescent, with only a very small amount of red-brown flocculent matter. Distinct sewage smell mixed with sea-weed smell. Reaction very acid, and still slightly acid after boiling. Very little lime in solution and only a moderate amount of sulphate. A good deal of ferric iron (mostly in suspension), and a little ferrous, I think.

NOTE.—The following + corrections have been made in the figures for nitric nitrogen, to allow for loss of nitrite when boiling down for nitrate; and the corresponding — corrections in the figures for "X" and organic nitrogen:—·01 in Nos. 82 and 85; ·03 in No. 87.

ALDERSHOT CAMP SEWAGE FARM, 1900–1.

Sewages, with Effluents from New Land "A."

84 Effluent from same Source as Nos. 82 & 83.	85 Effluent from same Source as No. 84.	86 Settled Sewage from Tanks.	87 Effluent from New Land "A" corresponding to Sewage No. 86.	88 Effluent from New Land "A"
Wednesday 30th May 1900, 3.15 p.m.	Thursday 31st May 1900, 2.45 p.m.	Tuesday 5th June 1900, 12.45 Noon.	Tuesday 5th June 1900, 3 p.m.	Wednesday 6th June 1900, 3.15 p.m.
11·7° C. (53° F.)	11·7° C. (53° F.)	15·6° C. (60° F.)	12·2° C. (54° F.)	12·8° C. (55° F.)
17·7° C. (63° F.)	10·6° C. (51° F.)	14·4° C. (58° F.)	14·4° C. (58° F.)	16·1° C. (61° F.)
—	—	—	—	—
31st May 1900.	1st June 1900.	6th June 1900.	6th June 1900.	7th June 1900.
2·36	2·20	9·00	3·08	4·04 approx.
2·47	1·96	9·06	2·96	3·64
0·49	0·45	2·06	0·49	0·55
0·11	0·07	None.	0·12	None.
0·15	0·09	Not done.	0·36	None.
3·28	3·07	12·45	4·06	4·64
(0·19 in 4·86)	(0·19 in 4·61)	(0·19 in 9·23)	(0·19 in 6·0)	(0·19 in 6.92)
+0·06	+0·03	None.	+0·06	None.
0·06	0·50	1·33	0·13	0·45
0·55	0·95	3·39	0·62	1·00
0·72	0·66	4·67	0·97	—
0·61	0·90	4·61	1·09	0·75
1·67	1·51	4·81	2·80	4·83
7·84	6·91	20·81	9·64	17·16
2·02	1·49	—	4·77 } Six days.	5·82
7·33	6·44	—	11·37 } Six days.	17·77
Sulphide smell.	Strong smell of sulphuretted hydrogen.	—	Putrid.	Putrid.
—	6·90	9·34	8·90	—
—	143·93	—	162·74*	—
—	0·20	—	0·08	—
—	16·03	—	15·61	—
Deep brown in colour. Practically no suspended matter. Seaweed or faint sewage smell. Strongly acid. *Note.*—It was not worth while to boil out this sample.	This sample was still very brown, but a great deal less so than the previous samples from the new land. Opalescent. Small specks of (apparently) vegetable matter coloured red-brown. Seaweed smell. Strongly acid, but quite alkaline on boiling. Very little lime and not very much sulphate in solution. A moderate amount of iron (ferrous and ferric), no doubt mostly colloïdal.	Considerable dark brown sediment. Faint sewage smell. Strongly alkaline.	Excessively brown, but contained only a little red brown flocculent matter. Strongly acid, but alkaline on boiling. A mixture of seaweed and sewage smell (sewage on boiling). Very little lime indeed in solution, and a moderate amount of sulphate. Only a little ferrous and ferric iron (the colour being due to organic matter).	Very dark brown, with a few floating particles. Sea-weed or urinous smell. Acid in the cold; alkaline on warming. * This is a very large quantity.

ALDERSHOT CAMP FARM, 1901.

Sewage, with Effluents from New Land "A."

No. of Sample	No. 320	321	321	322
Nature of Sample	Sewage drawn just before going on to New Land "A."	Final Effluent from New Land "A."	Small Duplicate.	Final Effluent from New Land "A."
Drawn	Wednesday, 17th July 1901, 10.45 a.m.	Wednesday, 17th July 1901, 12.30 noon.	—	Thursday, 18th July 1901, 11.35 a.m.
Temperature of sample	25·6° C. (78° F.)	15·0°C. (59° F.)	—	15·0° C. (59° F.)
Temperature of air	26·7° C. (80° F.)	27·2° C. (81° F.)	—	29·4° C. (85° F.)
If jointed or incubated	—	—	Jointed and incubated 18th July.	—
Analysed	18th July 1901.	18th July 1901.	Opened 22nd July 1901.	19th July 1901.
Parts per 100,000 *by weight.*				
Ammoniacal nitrogen :				
(a) by direct Nesslerization	12·12	2·72	—	—
(b) by distillation	11·62	2·44	—	2·68
Albuminoid nitrogen	2·05	0·35	—	0·42
Nitrous "	None.	None.	—	None.
Nitric "	Not done.	0·27	—	None (−0·03)
Total nitrogen by Kjeldahl *with* reduction.	15·27	Jy.20. Aug.1. Aug.14 2·87 2·58 2·55	—	3·29
Blank	(0·30 in 11·36)	(0·3in4·45 ; 4·04 ; 3·99)	—	(0·30 in 5·07)
"X" Nitrogen	1·60	None.	—	0·19
Organic nitrogen by Kjeldahl, *with* reduction.	3·65	0·35	—	0·61
Organic nitrogen by Kjeldahl, *without* reduction :				
(a) Taking ammonia by direct Nesslerization.	3·00	0·24	—	—
(b) Taking ammonia by distillation	3·59	0·52	—	0·60
Oxygen absorbed from permanganate at 26·7° C. (80° F.) ; *at once.*	6·50	1·65	—	1·95
" " " *after four hours.*	20·68	7·28	—	8·14
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C, (80° F.) ; *at once*	—	1·98	-	2·16
" " " *after four hours.*	—	7·33	—	8·26
Smell after incubation	—	Suspicious ; No nitrite.	—	Slightly putrid. No nitrite.
Chlorine	10·18	9·84	—	9·70
Parts per 100,000 *by volume.*				
Solids by centrifuge	346·0 (1 minute).	10·0 (1 minute)	—	35·0 (1 minute).
Gases : Parts per 1 000 *by volume.*				
Oxygen (by cuprous chloride) : When sample was analysed	—	None.	—	None.
Remarks	Very considerable sediment, which was dark brown (almost black) in colour. Fairly strong sewage smell. Alkaline.	This sample had a deep brown colour, even when filtered, and it contained a small quantity of light brown sediment. Seaweed smell. Nearly neutral till boiled, and then alkaline.	When opened on 22nd July, this liquid had blackened and it had a suspicious smell. It was rejointed and reopened on 24th July. It was now rather blacker and had a distinctly putrid smell, and the vapours browned acetate of lead paper. Not analysed.	Very turbid, and dark brown, even when filtered. Small amount of brown sediment ; slight seaweed smell. Faintly acid from carbonic acid. Alkaline on boiling.

ALDERSHOT CAMP FARM, 1901.

Sewage, with Effluents from New Land "A."

322 Small Duplicate.	323 Final Effluent from New Land "A." (Just trickling when drawn).	323 Large Duplicate.	324 Final Effluent from New Land "A." (Small sample).	324 Large Duplicate.	325 Final Effluent from New Land "A."	325 Small Duplicate.
—	Monday, 22nd July 1901, 11 a.m.	—	Tuesday, 23rd July 1901, 11.15 a.m.	—	Wednesday, 24th July 1901, 10 a.m.	—
—	15·0° C. (59° F.)	—	15·0° C. (59° F.)	—	15° C. (59° F.)	—
—	20·0° C. (68° F.)	—	18·9° C. (66° F.)	—	18·9° C. (66° C.)	—
ncubated 19th July. Jointed 22nd July. pened 25th July 1901.	—	Jointed 24th July	Jointed and incubated 24th July.	Jointed 24th July.	—	Jointed and incubated 25th July.
	23rd July 1901.	Opened 29th August 1901.	Opened 1st August 1901.	Opened 29th August 1901.	25th July 1901.	Opened 1st August 1901.
—	—	—	—	—	—	—
—	4·39	—	—	—	8·11	—
—	2·46	—	—	—	0·65	—
—	None.	—	—	—	None.	—
—	0·42	—	—	—	None.	—
—	—	—	—	—	9·31	—
—	—	—	—	—	(0·30 in 13·78)	—
—	—	—	—	—	0·55	—
—	—	—	—	—	1·20	—
—	—	—	—	—	—	—
—	—	—	—	—	1·07	—
—	12·56	—	—	—	2·38	—
—	—	—	—	—	7·87	—
—	—	—	—	—	4·28	—
—	—	—	—	—	8·03	—
—	—	—	—	—	Very putrid.	—
—	—	—	—	—	13·40	—
—	1220·0 (1 minute.)	—	—	—	14·0	—
—	—	—	—	—	None.	—
When opened, this smelt slightly putrid, and the vapours blackened acetate of lead paper. Not analysed.	The above sample was very turbid, brown and muddy. It had a yellow tinge when filtered. Strong but clean seaweed smell. Alkaline. The above is virtually a sewage. *Note.*—This was only a small bottle.	When opened, this was inky-black and very putrid, and smelling strongly of sulphuretted hydrogen. Not analysed.	Blackened and putrid, with sulphide smell. Not analysed.	When opened, liquid was brown-black with black sediment. Putrid. Not analysed.	This sample was deep brown, even after filtering. Rather turbid, with a small amount of brown deposit. Suspicious and seaweed smell. Alkaline.	When opened, this was blackened and putrid, and smelt of sulphuretted hydrogen. Not analysed.

ALDERSHOT CAMP SEWAGE FARM, 1901–2.

Effluents from New Land "A."

No. of Sample	No. 404	404	461	463
Nature of Sample	Final Effluent from New Land "A."	Small Duplicate.	Final Effluent from New Land "A."	Final Effluent from New Land "A."
Drawn	Thursday 17th October 1901, 11·20 am.	—	Tuesday 28th January 1902, 12 noon	Wednesday 29th January 1902, 3 p.m.
Temperature of sample	11·1° C. (52° F.)	—	4·4° C. (40° F.)	1·7° C. (35° F.)
Temperature of air	10·6° C. (51° F.)	—	7·2° C. (45° F.)	0° C. (32° F.)
If jointed or incubated	—	Jointed and incubated, 18th October.	—	—
Analysed	18th October 1901.	Opened 27th November 1901.	29th January 1902.	30th January 1902.
Parts per 100,000, *by weight.*				
Ammoniacal nitrogen: (a) by direct Nesslerization	—	—	—	—
(b) by distillation	4·52	—	1·18	†0·59
Albuminoid nitrogen	0·38	—	0·12	0·07
Nitrous ,,	None	—	None.	None.
Nitric ,,	0·31	—	6·32 (30th January)	6·26
Total nitrogen by Kjeldahl, *with* reduction.	5·35	—	7·79	7·84
Blank	(0·30 in 8·11)	—	(0·25 in 11·68)	(0·25 in 11·76)
"X" nitrogen	0·14	—	0·17	(?)
Organic nitrogen by Kjeldahl, *with* reduction.	0·52	—	0·29	(?)
Oxygen absorbed from permanganate at 26·70° C. (80° F.); *at once.*	1·18	—	0·31	0·11
,, ,, ,, *after four hours.*	5·25	—	1·22	0·71
Oxygen absorbed from permanganate by sample incubated for five days at 26·70° C. (80° F.); *at once*	1·61 (Twelve days.)	—	0·31 (Seven days.)	0·20 (Six days.)
,, ,, ,, *after four hours.*	4·66	—	1·11	0·84
Smell after incubation	Putrid.	—	Sweet, no nitrite.	Sweet, no nitrite.
Chlorine	8·92	—	8·60	10·60
Total Solids (Gravimetrically)	—	—	84·4 (20·2 Volatile, 64·2 Non-Vol.)	86·1 (18·6 Volatile, 67·5 Non-Vol.)
Solids in suspension (by dif.)	—	—	*0·3 (?)	*0·7 (0·0 (?), 0·7 (?))
Solids in Solution	—	—	84·1 (19·0 Volatile, 65·1 Non-Vol.)	85·4 (18·6 Volatile, 66·8 Non-Vol.)
Part per 1,000 *by volume.*				
Solids by centrifuge	27·0 (3 minutes)	—	14·0 (3 minutes.)	52·0 (3 minutes.)
Gases; Parts per 1,000 *by volume.*				
Oxygen (by cuprous chloride): When sample was analysed	None.	—	5·0, 5·0, 5·0 (Three Observers) Compared with Standards 4 & 6. Standards weakened	Just under 4·0, 4·5, 5·0 (Three Observers.)
Remarks	This effluent had a sewage smell when it was drawn. On 18th October it was of a deep yellow colour with a considerable amount of buff-coloured suspended matter. Very strong earthy smell. Alkaline.	When opened this was blackened and putrid, with a smell of sulphuretted hydrogen. Not analysed.	This sample was almost colourless, with only a slight yellow tinge. Only a very little yellow flocculent sediment, which looked like weed of some kind. Rather fishy smell. Alkaline.	Almost colourless, *i.e.*, only very slightly yellow. Very little yellowish-brown flocculent sediment, apparently weed, but more than in No. 461. Rather fishy smell. Alkaline.

* *Note.*—100 C.C. (the quantity taken) was really too little for the gravimetric estimation, by difference, of the suspended solids in such effluents.

† *Note.*—There is a little doubt here as to a possible clerical error; if there was such an error, the ammoniacal nitrogen should be doubled.

ALDERSHOT CAMP SEWAGE FARM, 1901.

Sewage and Effluents from New Land "B."

ALDERSHOT CAMP SEWAGE FARM, 1901.

Sewage and Effluents from New Land "B."

No. of Sample	No. 306	307	307	309	309
Nature of Sample	Settled Sewage.	Effluent from New Land "B" corresponding to Sewage No. 306.	Small Duplicate.	Final Effluent from New Land "B" (Rye Grass.)	Small Duplicate.
Drawn	Monday 24th June 1901, 11.30 a.m.	Monday 24th June 1901, 12.45 noon.	—	Tuesday 25th June 1901, 12.15 noon.	—
Temperature of sample	17·8° C. (64° F.)	12·2° C. (54° F.)	—	12·8° C. (55° F.)	—
Temperature of air	19·4° C. (67° F.)	20·0° C. (68° F.)	—	18·9° C. (66° F.)	—
If jointed or incubated	—	—	Jointed and incubated 25th June.	—	Jointed and incubated 26th June.
Analysed	25th June 1901	25th June 1901	1st July 1901	26th June 1901.	8th July 1901.
Parts per 100,000, *by weight.*					
Ammoniacal nitrogen:					
(a) by direct Nesslerization	—	2·72	—	2·64	—
(b) by distillation	13·13	2·42	2·30	2·76	2·98
Albuminoid nitrogen	3·20	0·24	0·30	0·29	0·34
Nitrous "	Trace.	None.	Trace.	None.	None.
Nitric "	Not done.	0·27	0·19	0·10	None.
Total nitrogen by Kjeldahl, *with* reduction.	16·79	3·03	—	*3·53 (5th July)	—
Blank	(0·24 in 12·40)	(0·24 in 4·63)	—	(0·24 in 5·35)	—
"X" nitrogen	0·46	0·10	—	0·38	—
Organic nitrogen by Kjeldahl, *with* reduction.	3·66	0·34	—	0·67	—
Organic nitrogen by Kjeldahl, *without* reduction:					
(a) Taking ammonia by direct Nesslerization.	—	—	—	0·47	—
(b) Taking ammonia by distillation	—	None or 0·10	—	0·35	—
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once.*	5·00	0·65	0·63	1·13	1·75
" " " *after four hours.*	20·76	4·08	—	4·97	—
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once*	—	0·54 (Six days)	—	0·92	—
" " " *after four hours.*	—	4·02 (Six days)	—	4·74	—
Smell after incubation	—	Sweet, no nitrite or only a trace.	Clean.	Sweet, strong; trace of nitrite.	Suspicious.
Chlorine	11·38	10·18	—	10·58	—
Parts per 100,000, *by volume.*					
Solids by centrifuge	118·0 (1 minute)	2·5 (1 minute)	—	1·0 (1 minute)	—
Gases: Parts per 1,000, *by volume.*					
Oxygen (by cuprous chloride):					
When sample was analysed	—	Trace. ?	—	Doubtful trace.	—
Remarks	Moderately turbid and brown, with considerable dark brown sediment. Strong sewage smell. Alkaline.	This was slightly turbid and very brown, with but a very small amount of buff-brown and grey suspended matter. Earthy smell. Acid from carbonic acid.	After incubation this was very brown and fairly clear. One small piece of brown sediment. Clean smell.	Deep brown, even when filtered. Practically no sediment. Clean smell. Acid from carbonic acid, but alkaline on boiling.	After incubation this was deep brown, even when filtered. Practically no sediment. Suspicious smell.

* *Note.*—The "Kjeldahl" begun on 26th June, showed no organic nitrogen, so this analysis is not very satisfactory. It is difficult to see how the above sample kept non-putrescent, with 0·67 organic nitrogen and only 0·10 nitric nitrogen.

ALDERSHOT CAMP SEWAGE FARM, 1901.

Effluents from New Land "B."

312 Final Effluent from New Land "B."	No. 313 Final Effluent from New Land "B."	313 Small Duplicate.	317 Final Effluent from New Land "B."	317 Small Duplicate.	318 Final Effluent from New Land "B."	318 Small Duplicate.
Tuesday 2nd July 1901, 1 p.m.	Wed. 3rd July 1901, 11 a.m.	—	Tuesday 9th July 1901, 11 a.m.	—	Wed. 10th July 1901, 11.49 a.m.	—
12·8° C. (55° F.)	12·8° C. (55° F.)	—	13·9° C (57° F.)	—	14·4° C. (58° F.)	—
16·1° C. (61° F.)	20·0° C. (68° F.)	—	20·0° C. (68° F.)	—	24·4° C. (76° F.)	—
—	—	Jointed and incubated 4th July.	—	Jointed and incubated, 10th July.	—	Jointed and incubated 11th July.
Opened 4th July 1901.	4th July 1901.	30th July 1901.	11th July 1901.	Opened 7th August 1901.	11th July 1901.	Opened 7th August 1901.
—	—	—	Not done. Liquid too dark.	—	Not done; too dark coloured.	—
—	2·14	2·09 } 2 drops sod. carb. solution added.	1·81	—	2·25	—
—	0·33	0·32 }	0·23	—	0·26	—
—	None	None.	0·02	—	None.	—
—	0·40	0·07	0·01	—	0·02	—
—	3·04	—	2·14	—	2·69	—
—	(0·24 in 4·64)	—	(0·30 in 3·40)	—	(0·30 in 4·19)	—
—	0·17	—	0·07	—	0·16	—
—	0·50	—	0·30	—	0·39	—
—	—	—	—	—	—	—
—	0·38	—	0·31	—	0·04	—
—	1·67	2·93	1·10	—	0·93	—
—	7·24	—	4·19	—	4·34	—
—	1·84	—	0·95	—	1·26	—
—	7·12	—	4·14	—	4·54	—
—	Sweet, no nitrite.	Putrid, with a slight smell of sulphuretted hydrogen.	Sweet, no nitrite.	—	Sweet, no nitrite.	—
—	9·76	—	9·40	—	9·72	—
—	19·0 (1 minute)	—	8·0 (1 minute)	—	2·5 (1 minute)	—
—	None.	—	None.	—	None.	—
When opened on 4th July, this was smelling and very turbid, more turbid than it was originally. It was therefore rejointed on 4th July, with the admission of only a very small air-bubble. On 9th July it was blackened, and had — curiously — a fresh sewage smell. Not analysed.	Dark brown, even when filtered. Very little suspended matter. Clean earthy smell. Strongly acid from carbonic acid, and just alkaline when boiled.	After incubation, brown and turbid, with a putrid and slight sulphuretted hydrogen smell. A small amount of brown sediment. *Note.*—Assuming that those two bottles No. 313, were real duplicates, the analyses show the different effects of different lengths of time for incubation.	Deep brown colour even when filtered; a little less coloured than No. 318, but containing rather more suspended matter. Seaweed smell. Acid from carbonic acid, tending to alkaline on boiling. *Note.*—It is noteworthy that this should have kept on incubation.	When opened, this incubated effluent was still yellow-brown, but it was putrid and smelt strongly of sulphuretted hydrogen, which darkened acetate of lead paper. The liquid itself did not blacken. *Cf.* Note to Sample No. 318, duplicate. Not analysed. *Note.*—The note made with regard to No. 313 and duplicate also applies to 317 and duplicate.	Dark brown and slightly cloudy. The colour was not appreciably lessened by filtering. Clean seaweed smell. Acid from carbonic acid, tending to alkaline on boiling. Noteworthy that this should not have gone putrid on incubation.	When opened this effluent was still yellow-brown, but it was putrid and smelt strongly of sulphuretted hydrogen, which darkened acetate of lead paper. About an hour after opening, the colour changed from yellow-brown to intense greenish black. Not analysed.

ALDERSHOT CAMP SEWAGE FARM, 1901.

Street Washings.

No. of Sample	No. 311	311	314
Nature of Sample	Street Washings from Surface Water Ditch.	Small Duplicate.	Street Washings.
Drawn	Tuesday, 2nd July 1901, 12.45 noon.	—	Wednesday, 3rd July 1901, 11.45 a.m.
Temperature of sample	16·1° C. (61° F.)	—	15·6° C. (60° F.)
Temperature of air	16·1° C. (61° F.)	—	21·1° C. (70° F.)
If jointed or incubated	—	Jointed and incubated, 3rd July. Rejointed, 22nd July.	—
Analysed	3rd July 1901.	Opened, 24th July 1901.	4th July 1901.
Parts per 100,000, *by weight.*			
Ammoniacal Nitrogen:			
(a) by direct Nesslerization	0·49	—	1·66
(b) by distillation	0·49	—	1·70
Albuminoid nitrogen	0·49	—	0·34
Nitrous ,,	Trace. (?)	—	None.
Nitric ,,	0·12	—	0·02
Total Nitrogen by Kjeldahl, *with* reduction.	1·66	—	2·36
Blank	(0·24 in 2·64)	—	(0·24 in 3·66)
"X" nitrogen	0·56	—	0·30
Organic nitrogen by Kjeldahl, *with* reduction.	1·05	—	0·64
Organic nitrogen by Kjeldahl, *without* reduction:			
(a) Taking ammonia by direct Nesslerization.	0·75	—	0·83
(b) Taking ammonia by distillation	0·75	—	0·79
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once.*	2·76	—	0·81
,, ,, ,, *after four hours.*	8·93	—	3·46
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once*	4·08	—	1·97
,, ,, ,, *after four hours.*	9·94	—	3·92
Smell after incubation	Black and smelling of sulphuretted hydrogen.	—	Black and smelling of sulphides.
Chlorine	1·40	—	4·54
Parts per 100,000, *by volume.*			
Solids by centrifuge	Not done, because of large amount of grit.	—	65·0 (one minute)
Gases: parts per 1,000 *by volume.*			
Oxygen (by cuprous chloride):			
When sample was analysed	Too turbid.	—	None.
Remarks	Turbid and brown, but the liquid had only a slight brown tinge when filtered. A great deal of sand, and also brownish suspended matter. Clean smell. Almost neutral, tending to alkaline.	When opened this was blackened, distinctly putrid, and smelling of sulphuretted hydrogen. Not analysed.	This was turbid and brown. It had a muddy appearance from considerable suspended matter, with grit at bottom of bottle. Very slight putrid smell. Alkaline.

ALDERSHOT CAMP SEWAGE FARM, 1900–1901.

Well Water; Brook Water alone and admixed with Effluent.

o. of Sample	No. 60	56	57	58	59	59
ature of Sample	Well Water to represent subsoil water. Well 8′ 6″ deep with 3′ 6″ of water in it.	General Effluent from low unchalked Land.	River Water above effluent outfall.	River Water containing effluent. Drawn immediately below the Junction.	River Water containing effluent. Drawn 170 yds. below Junction.	Duplicate.
rawn	Monday, 2nd April 1900, 12 noon.	Tuesday, 27th March 1900, 12.15 noon.	Tuesday, 27th March 1900, 12.30 noon.	Tuesday, 27th March 1900, 12.45 noon.	Tuesday, 27th March 1900, 1.15 p.m.	—
emperature of sample	7·2° C. (45° F.)	7·8° C. (46° F.)	5·6° C. (42° F.)	5·8° C. (42·3° F.)	5·8° C. (42·3° F.)	—
emperature of air	—	—	—	—	—	—
jointed or incubated	—	—	—	—	—	Jointed.
nalysed	3rd April 1900.	28th March 1900.	30th March 1900.	29th March 1900.	29th Mar. 1900.	3rd May 1900.
Parts per 100,000 *by weight.*						
mmoniacal nitrogen:						
(a) by direct Nesslerization	Too dilute.	—	Turbid.	Turbid.	Turbid.	Turbid.
(b) by distillation	0·001	4·98	0·61	0·99	0·88	1·06
lbuminoid nitrogen	0·016	0 45	0·19	0·15	0·15	0·10
itrous ,,	None.	0·09	None.	None.	None.	None.
itric ,,	0·11	1·51	0·31	0·62	0·61	0·34
otal nitrogen by Kjeldahl, *with reduction* (after nitrite correction).	Not done.	7·71	1·10	1·92	1·69	1·64
lank	—	(0·22 in 11·36)	(0·22 in 1·81)	(0·23 in 3·02)	(0·22 in 2·68)	(0·19 in 2·57)
orrection for nitrite	—	+0·04	None.	None.	None.	None.
X" nitrogen	—	0·68	None (–0·01)	0·16	0·05	0·14
rganic nitrogen by Kjeldahl, *with* reduction.	—	1·13	0·19	0·31	0·20	0·24
rganic nitrogen by Kjeldahl, *without* reduction: Taking ammonia by distillation	0·061	0·47	0·16	0·21	0·34	0·25
xygen absorbed from permanganate at 26·7° C. (80° F.); *at once.*	0·102	0·95	0·04	0·20	0·25	0·05
,, ,, ,, *after four hours.*	0·761	5·68	1·02	1·46	1·49	1·02
xygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once*	Not done.	0·97	0·13	0·48	0·25	0·21
,, ,, ,, *after four hours.*	,,	3·76	0·88	1·45	1·30	1·30
nell after incubation	—	Distinctly putrefactive.	Sweet.	Doubtful.	Sweet (?)	Sweet.
hlorine	1·16	10·26	3·70	4·40	4·32	—
Gases: Parts per 1,000 *by volume.*						
arbon Dioxide (free)	8·57	81·44	21·37	24·98	25·90	29·54
xygen (boiled out)	2·05	3·10 *	6·89	6·51	6·77	0·02
itrogen	17·43	18·05	17·66	17·50 This was transferred to a 250 C.C. flask and drawn in from that.	17·49	18·24*
emarks	Clear, excepting for a small amount of greyish-brown flocculent matter. Neutral. No smell. Moderate amount of lime and sulphate in solution, and a trace of iron. Pure enough, but evidently containing some oxidizable matter.	This effluent was a little polluted, but it was originally a very bad one. Turbid, with very considerable brown flocculent matter. Slight, but distinct putrefactive odour; slightly acid. Very considerable amount of lime, and a great deal of sulphate in solution. *Note.—The presence of this large amount of oxygen in a bad effluent must be due to the low temperature.	Opalescent, with appreciable though not very great amount of brown flocculent matter. No smell. Slightly alkaline. A great deal of lime and a considerable amount of sulphate in solution. Though well aerated, this is not satisfactory for a river water.	Opalescent, with appreciable brown flocculent matter (rather aggregated). Clean earthy smell. Slowly alkaline. Much lime in solution, and a very considerable amount of sulphate.	Opalescent, with quite an appreciable amount of brown flocculent matter. Clean earthy smell. Very slowly alkaline. Much lime and sulphate in solution.	The flocculent matter had aggregated somewhat. Clean earthy smell. Very slightly alkaline. The above sample had exhausted all its dissolved oxygen and half of its nitrate. *Note.—Water had oozed through the mercury joint, and there was a small bubble of gas at the top of the bottle (say, 0·1 to 0·2 C.C.).

Note.—A + correction of ·01 has been made in the figure for nitric nitrogen in Nos. 315, 316, 316 jointed, 326, and 327, to allow for the loss of nitrite in boiling down for nitrate, and a corresponding – correction in the figures for "X" and organic nitrogen.

ALDERSHOT CAMP SEWAGE FARM, 1901

Brook Water alone and admixed with Effluent.

No. of Sample	No. 315	315	316
Nature of Sample	Brook Water above effluent outfall.	Small Duplicate.	Brook Water drawn 30 yards below outfall.
Drawn	Monday, 8th July 1901, 11.30 a.m.	——	Monday, 8th July 1901, 12 noon.
Temperature of sample	20·0° C. (68° F.)	——	20·0° C. (68 F.
Temperature of air	19·4° C. (67° F.)	——	20·0° C. (68° F.)
If jointed or incubated	——	Jointed and incubated, 9th July.	——
Analysed	10th July 1901.	22nd July 1901.	10th July 1901.
Parts per 100,000 *by weight.*			
Ammoniacal nitrogen :			
(a) by direct Nesslerization	3·20	——	3·36
(b) by distillation	2·83	2·81	2·78
Albuminoid nitrogen	0·15	0·24	0·21
Nitrous "	0·09	None.	0·09
Nitric "	0·04	0·02	0·84
Total nitrogen by Kjeldahl, *with* reduction.	3·20	——	4·08
Blank	(0·24 in 4·88)	——	(0·30 in 6·21)
"X" nitrogen	0·09	——	0·16
Organic nitrogen by Kjeldahl, *with* reduction.	0·24	——	0·37
Organic nitrogen by Kjeldahl, *without* reduction :			
(a) Taking ammonia by direct Nesslerization.	None (−0·14)	——	None (−0·20)
(b) Taking ammonia by distillation	0·23	——	0·38
Oxygen absorbed from permanganate at 26·7° C. (80° F.) ; *at once.*	0·50	0·40	0·65
" " " *after four hours.*	1·81	——	2·03
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.) ; *at once*	0·43	——	0·56
" " " *after four hours.*	1·61	——	2·02
Smell after incubation	Sweet, about 0·025 nitrite nitrogen.	Strong, but not putrid ; suspicious (?)	Sweet, no nitri
Chlorine	7·96	——	9·34
Parts per 100,000 *by volume.*			
Solids by centrifuge	24·0 (1 minute.)	7·0 (1 minute).	22·0 (1 minute.
Gases : Parts per 1,000 *by volume.*			
Oxygen (by cuprous chloride) :			
(a) When sample was drawn	5·0	——	3·0
(b) " " " analysed	1·0 / abt. 1·2 } Two observers	——	None on 10th.
Remarks	This sample was cloudy when drawn. On 10th July, it was turbid, with brown suspended matter ; yellow when filtered. Clean earthy smell. Alkaline.	After incubation this sample was fairly clear, with a slight yellow tinge and a small amount of brown sediment. Two observers gave the smell as (1) strong but not putrid ; (2) suspicious.	Cloudy blue when drawn. On 10th July turbid with a small amount of brownish sediment. Yellow when filtered. Clean smell (like seaweed ?) Alkaline.

ALDERSHOT CAMP SEWAGE FARM, 1901.

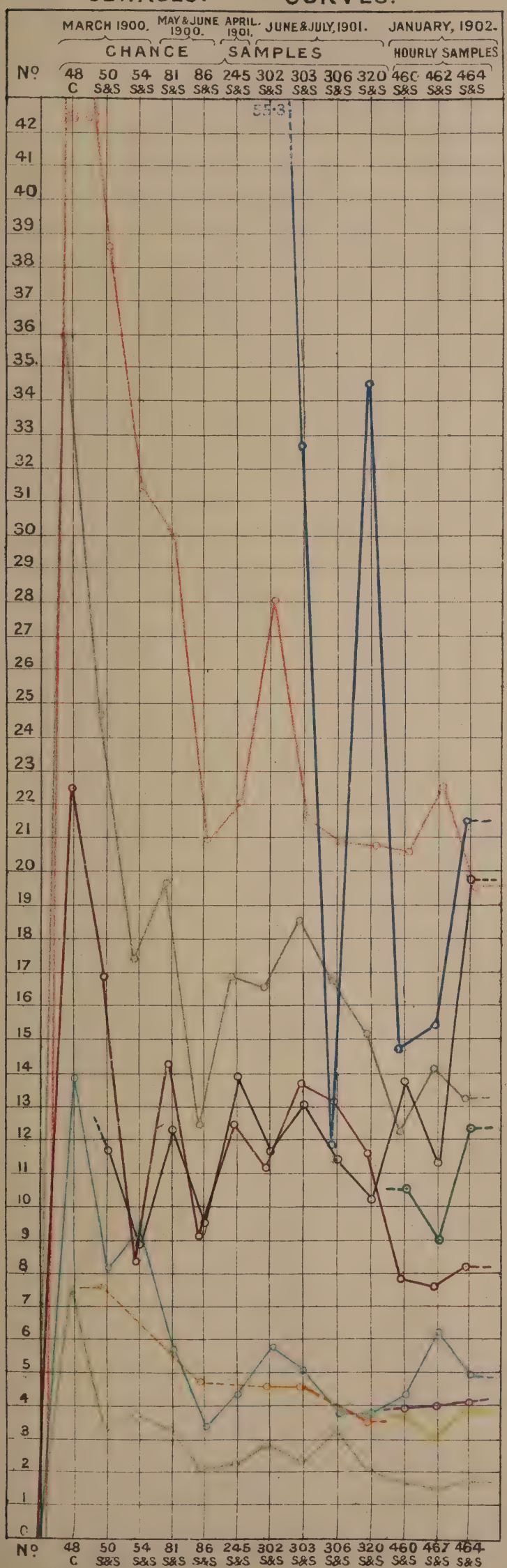
Brook Water alone and admixed with Effluent.

316 Small Duplicate	326 Brook Water 30 yards above effluent outfall.	326 Small Duplicate.	327 Brook Water 30 yards below effluent outfall.	327 Small Duplicate.
—	Wednesday, 24th July 1901, 10.35 a.m.	—	Wednesday, 24th July 1901, 11 a.m.	—
—	16·1° C. (61° F.)	—	16·1° C. (61° F.)	—
—	18·9° C. (66° F.)	—	18·9° C (66° F.)	—
Jointed and incubated, 9th July. 2nd August 1901.	— 26th July 1901.	Jointed and incubated, 25th July. 9th August 1901.	— 26th July 1901.	Jointed and incubated, 25th July (Joint changed, 31st July). 4th September 1901.
—	—	—	—	—
2·98	4·25	4·41	3·47	3·52
0·17	0·21	0·17	0·22	0·20
0·09	0·09	None.	0·08	Trace.
0·55	0·01	None.	0·51	0·26
—	4·76	—	4·26	—
—	(0·30 in 7·19).	—	(0·30 in 6·47)	—
—	0·20	—	*None (−0·02)?	—
—	0·41	—	0·22	—
—	—	—	—	—
—	None.	—	0·48	—
0·44	0·55	0·53	0·58	0·52
—	2·33	—	2·35	—
—	0·62	—	0·47	—
—	2·16	—	2·03	—
Clean.	Putrid; trace of nitrite (?)	Suspicious.	Sweet; trace of nitrite.	No smell.
—	11·42	—	10·70	—
—	6·0	—	29·0	—
—	—	—	—	—
—	None.	—	None.	—
After incubation this had a slight yellow tinge, with a small quantity of brown sediment. Clean smell.	Yellowish, even when filtered, and of a deeper tint than No. 327. Turbid, with a small amount of brown suspended matter. Earthy smell. Alkaline.	After incubation, brown, with slight brown sediment. Suspicious smell.	Yellow, even when filtered. Turbid; a small amount of brown suspended matter and much insect debris, chiefly gnat larvæ skins. Clean faint seaweed smell. * This must surely be wrong.	After incubation this had a slight yellow tinge, with a small amount of aggregated brown sediment. No smell.

Diagram No. 5

ALDERSHOT CAMP SEWAGE FARM.

SEWAGES. CURVES.



Nature of Sewage

C = C de

S&S = *Screened & Settled*

REFERENCE

Parts per 100.000. by Weight.

Albuminoid Nitrogen ..... *Shewn thus* ———

Organic Nitrogen by Kjeldahl, with Reduction ..... ———

Organic Nitrogen by Kjeldahl, without Reduction ..... ———

Ammoniacal Nitrogen ..... ———

Total Nitrogen by Kjeldahl, with Reduction ..... ———

"Oxygen absorbed" from Permanganate at 26·7°C (80°F.) in four hours ..... ———

Chlorine (Combined) ..... ———

Solids in Suspension (Gravimetrically) (Scale divided by 10) ..... ———

Cellulose ..... ———

Cellulose (still containing fat) ..... ———

Parts per 100.000. by Volume.

Solids in Suspension (by Centrifuge) (Scale divided by 10) ———

Note

Figures in the Vertical line represent "Parts per 100.000."

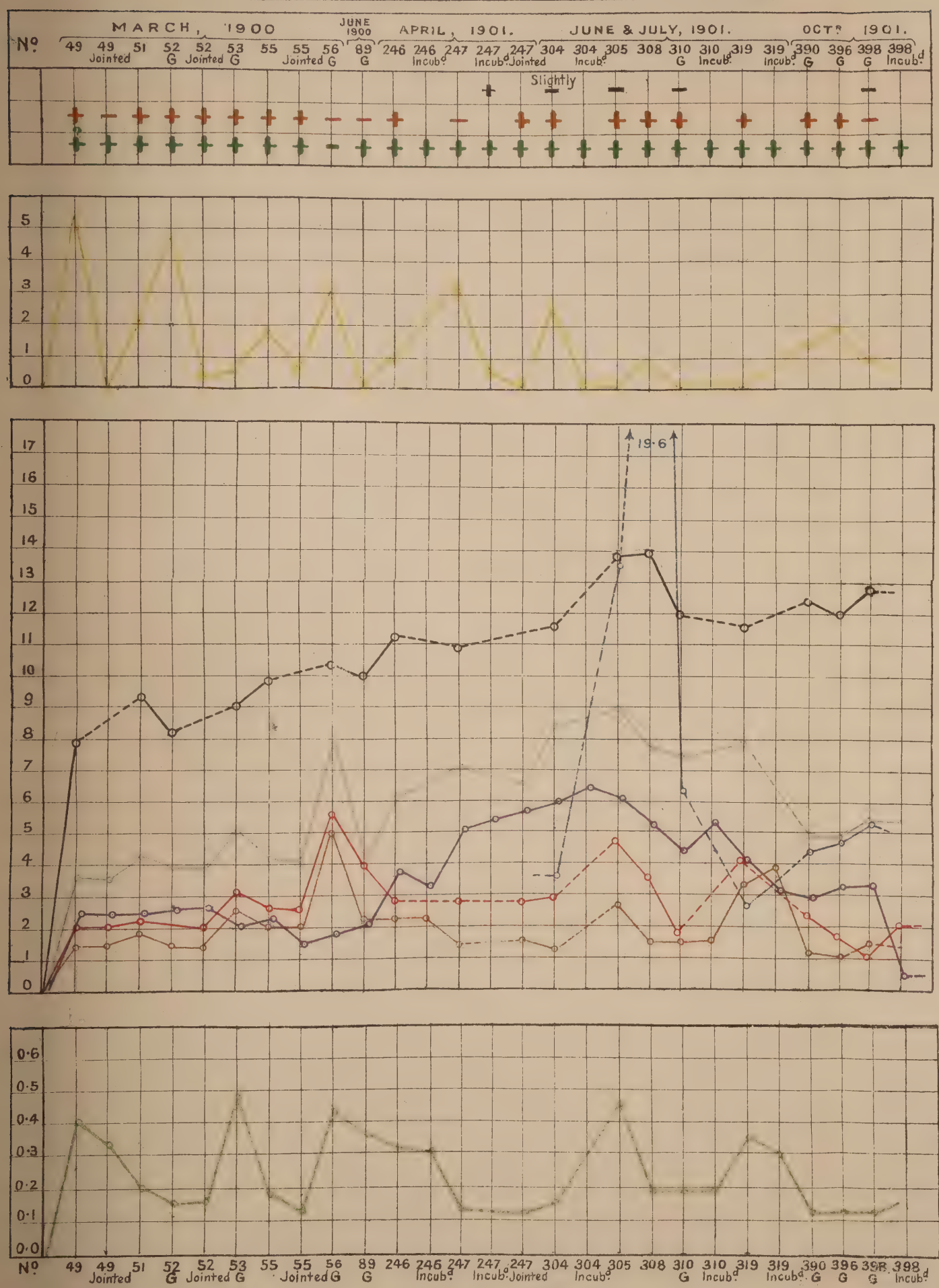
Figures in the Horizontal line represent the numbers of the Samples analysed.

A dotted line is used when there is a break in the curve.

Diagram No. 6.

ALDERSHOT CAMP SEWAGE FARM.

OLD LAND & GENERAL EFFLUENTS. CURVES.



REFERENCE

Smell of Samples when drawn Shewn thus + or −

Scudder's Incubation Test + −

Incubation test as judged by Smell + −

Parts per 1.000, by Volume (C.C. per Litre)

Dissolved Oxygen when sample was analysed

Parts per 100.000. by Weight.

Ammoniacal Nitrogen Shewn thus

Total Nitrogen by Kjeldahl. with Reduction

Nitric + Nitrous Nitrogen (together)

"Oxygen absorbed" from Permanganate at 26·7°C (80°F.) in four hours.

Chlorine (Combined)

Parts per 100.000. by Volume.

Solids in Suspension (by Centrifuge) (Scale divided by 10)

Parts per 100.000. by Weight.

Albuminoid Nitrogen Shewn thus

Note

G = General Effluent

Note

Figures in the Vertical line represent "Parts per 100.000."

Figures in the Horizontal line represent the numbers of the Samples analysed.

A dotted line is used when there is a break in the curve.

Note

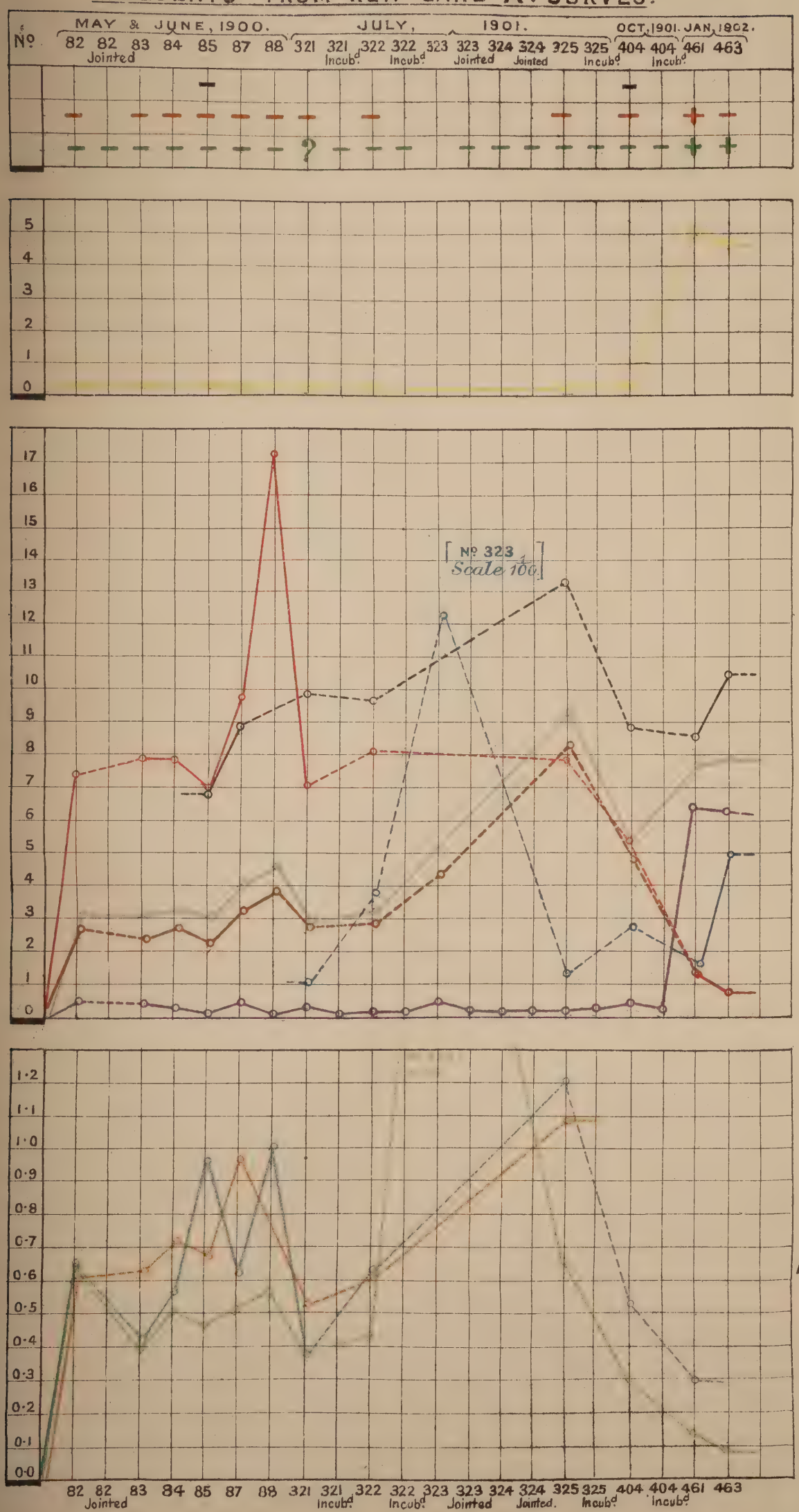
"Jointed" Indicates a sample jointed and allowed to stand at laboratory temperature.

"Incubated" Indicates a sample jointed and allowed to stand for five days or longer at a temperature of 26.7°C (80°F.)

Diagram No 7.

ALDERSHOT CAMP SEWAGE FARM.

EFFLUENTS FROM NEW LAND "A". CURVES.



REFERENCE

Smell of Samples when drawn Shewn thus + or −

Scudder's Incubation Test + −

Incubation test as judged by Smell + −

Parts per 1000, by Volume (C.C. per Litre)

Dissolved Oxygen when sample was analysed

Parts per 100.000, by Weight.

Ammoniacal Nitrogen. Shewn thus

Total Nitrogen by Kjeldahl. with Reduction.

Nitric + Nitrous Nitrogen (together)

"Oxygen absorbed" from Permanganate at 26·7°C (80°F.) in four hours.

Chlorine (Combined)

Parts per 100.000. by Volume.

Solids in Suspension (by Centrifuge) (Scale divided by 10)

Note

"Jointed" Indicates a sample jointed and allowed to stand at laboratory temperature.

"Incubated" Indicates a sample jointed and allowed to stand for five days or longer at a temperature of 26.7°C (80°F.).

Parts per 100.000, by Weight.

Albuminoid Nitrogen Shewn thus

Organic Nitrogen by Kjeldahl, with Reduction.

Organic Nitrogen by Kjeldahl, without Reduction

Note

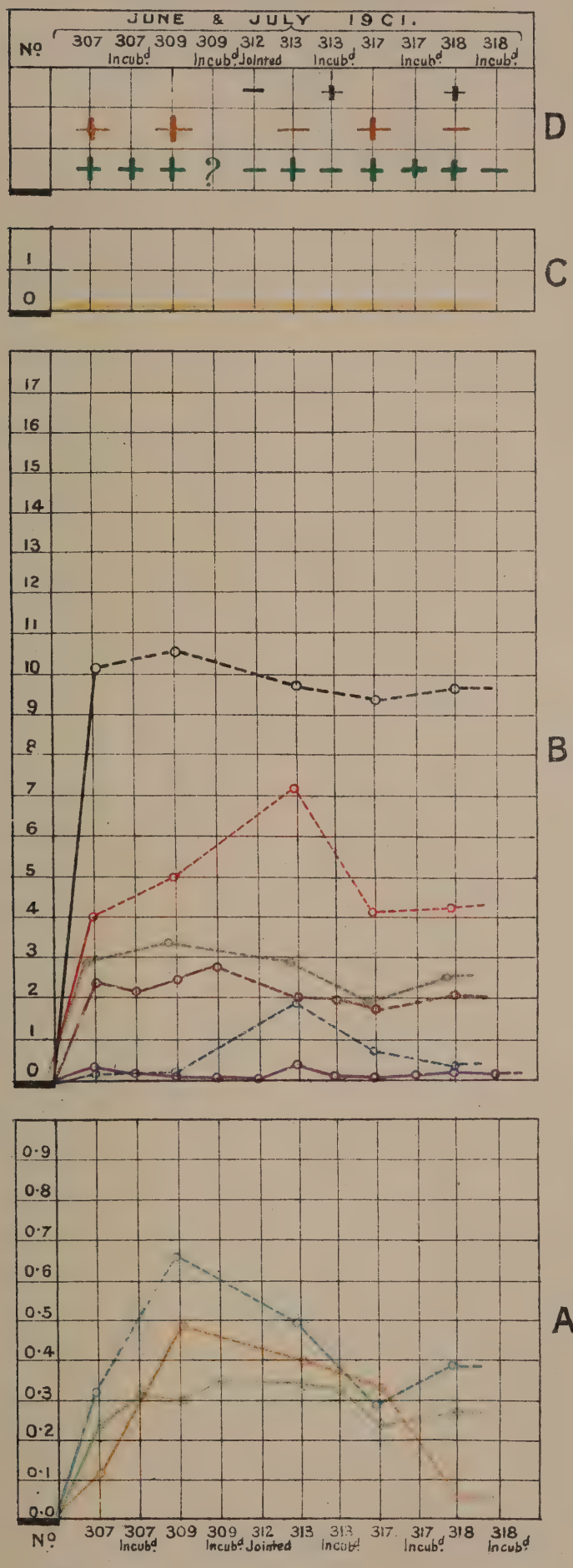
Figures in the Vertical line represent "Parts per 100.000."

Figures in the Horizontal line represent the numbers of the Samples analysed.

A dotted line is used when there is a break in the curve.

Diagram No. 8.

ALDERSHOT CAMP SEWAGE FARM.
EFFLUENTS FROM NEW LAND "B". CURVES.



REFERENCE

Smell of Samples when drawn Shewn thus + or −

Scudder's Incubation Test + −

Incubation test as judged by Smell + −

Parts per 1000, by Volume (C.C. per Litre)

Dissolved Oxygen when sample was analysed

Parts per 100.000, by Weight.

Ammoniacal Nitrogen Shewn thus

Total Nitrogen by Kjeldahl. with Reduction.

Nitric + Nitrous Nitrogen (together)

"Oxygen absorbed" from Permanganate at 26·7°C (80°F.) in four hours.

Chlorine (Combined)

Parts per 100.000. by Volume.

Solids in Suspension (by Centrifuge) (Scale divided by 10)

Parts per 100.000, by Weight.

Albuminoid Nitrogen Shewn thus

Organic Nitrogen by Kjeldahl, with Reduction.

Organic Nitrogen by Kjeldahl, without Reduction.

Note

"Jointed" Indicates a sample jointed and allowed to stand at laboratory temperature.

"Incubated" Indicates a sample jointed and allowed to stand for five days or longer at a temperature of 26.7°C (80°F.).

Note

Figures in the Vertical line represent "Parts per 100.000."

Figures in the Horizontal line represent the number's of the Samples analysed.

A dotted line is used when there is a break in the curve.

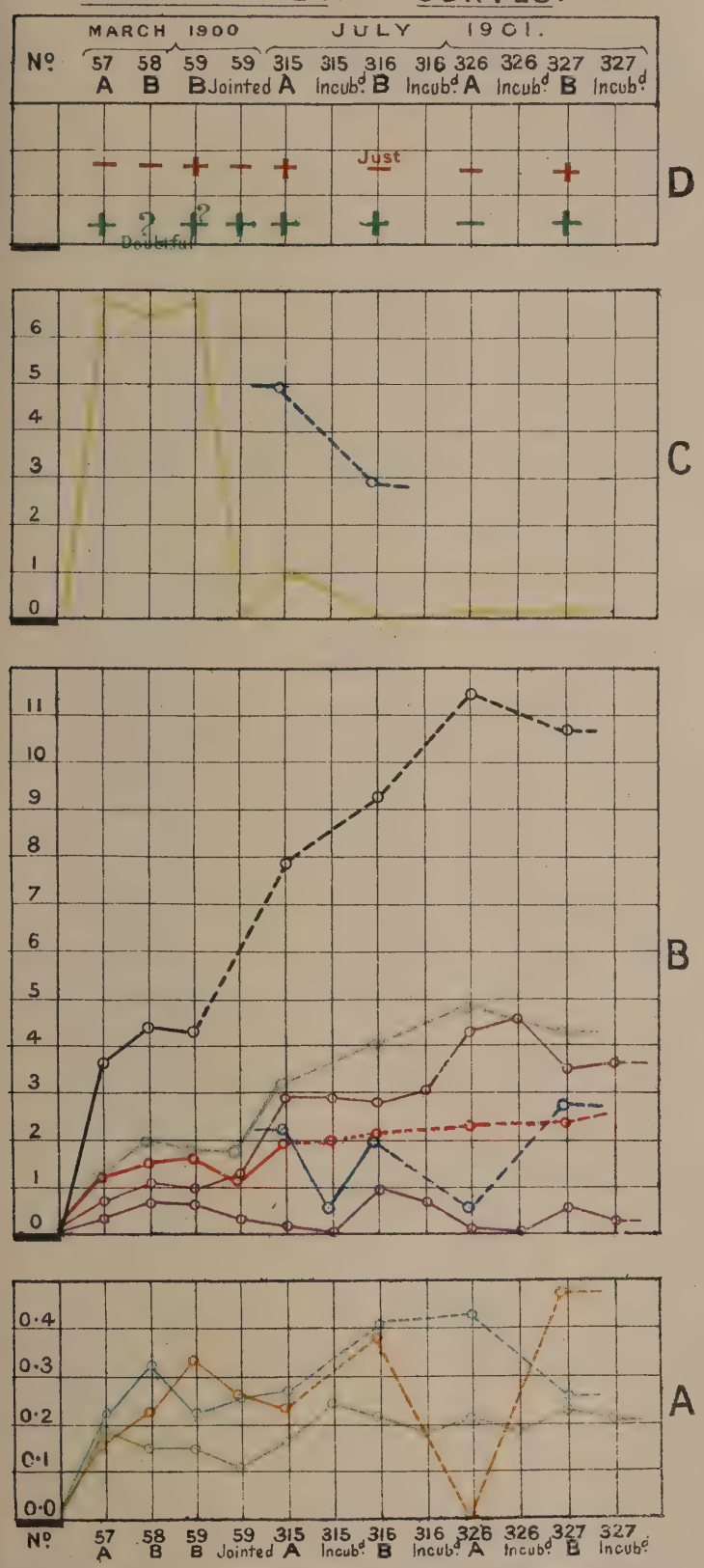
Weller & Graham Ltd Litho. Lon

3332.11.02.

Diagram No. 9.

ALDERSHOT CAMP SEWAGE FARM.

BROOK WATER. CURVES.



Note A Indicates a sample drawn from Above Effluent Outfall
B ,, ,, ,, ,, ,, ,, Below ,, ,,

"Jointed" Indicates a sample jointed and allowed to stand at laboratory temperature.

"Incubated" Indicates a sample jointed and allowed to stand for five days or longer at a temperature of 26.7°C (80°F.).

REFERENCE

Scudder's Incubation Test ..... + —

Incubation test as judged by Smell + –

Parts per 1000, by Volume (C.C. per Litre)

Dissolved Oxygen when sample was drawn Shewn thus

Dissolved Oxygen when sample was analysed.

Parts per 100.000, by Weight.

Ammoniacal Nitrogen..... Shewn thus

Total Nitrogen by Kjeldahl. with Reduction.

Nitric + Nitrous Nitrogen (together)

"Oxygen absorbed" from Permanganate at 26·7°C (80°F.) in four hours.

Chlorine (Combined)

Parts per 100.000. by Volume.

Solids in Suspension (by Centrifuge) (Scale divided by 10)

Parts per 100.000. by Weight.

Albuminoid Nitrogen..... Shewn thus

Organic Nitrogen by Kjeldahl, with Reduction.

Organic Nitrogen by Kjeldahl, without Reduction.

Note

Figures in the Vertical line represent "Parts per 100.000."

Figures in the Horizontal line represent the numbers of the Samples analysed.

A dotted line is used when there is a break in the curve.

3332. 11. 02.

Weller & Graham Ltd Litho. London.

ALTRINCHAM SEWAGE FARM.

Chemical Report.

1. Situation of farm—Bordering on Carrington Moss, about two miles from Altrincham.
2. Total acreage of farm—75·5 acres.
3. Total irrigable area—35 acres.
4. Average area irrigated at one time—17·5 acres.
5. Population draining to farm—18,000.
6. Population per acre irrigated—514.
7. Gallons of sewage per head per day—44·4.
8. Dry weather flow of sewage per 24 hours—800,000 gallons.
9. Gallons of sewage treated per acre per 24 hours—46,000.
10. Gallons of sewage treated per acre per 24 hours, on the assumption that each acre of the irrigable area is under sewage all the time—23,000.
11. Character of the sewage—Domestic.
12. Method of treatment—Settling tank and land filtration.
13. General character of the soil and subsoil—Peaty soil, lying upon sand and gravel.
14. Separate or combined sewerage system—Combined.
15. The final effluent is discharged into—Sinderland Brook.
16. Number of years farm in operation (before 1900)—30 years.

ALTRINCHAM SEWAGE FARM.

The Altrincham Sewage Farm, which has been in operation for fully 30 years, *i.e.*, since about 1870, may be taken as an instance of a peaty soil overlying sand admixed with some gravel, not peat pure and simple.

To quote from the Engineering Report :—" The soil varies in places, the surface soil consisting of 8in. to 10in. of black porous soil, mixed with, and resting upon, a layer of decomposed peat, 4in. to 7in. deep, superimposed upon fine white sand and gravel. About one half of the farm was formerly pure bog land (Carrington Moss); the remaining half or southern portion of the farm is of a sandier nature. *The actual peat land is not irrigated.* There is a large quantity of iron in the soil, and a "pan" of some 3in. to 6in. in thickness occurs in places."

The total irrigable area is 35 acres, of which 12 acres are in osier beds. About *half* of this irrigable area is sewaged at one time—a much larger proportion than at any of the other farms which have been under prolonged observation by the Commission.

The land is drained at an average depth of 3ft. 9in.

The sewage can only be treated *once.** *The effluents are therefore percolation effluents*, like those at Nottingham, Cambridge and Aldershot Camp.

* The lagoon liquor was sometimes passed from one lagoon into another before filtering through the soil.

Soil and Subsoil.

The following table gives the mechanical analysis, etc., of the soil (time did not permit of the subsoil being analysed). Though the various fractions of soil were not drawn in exactly the same way as the samples at the other six farms, they were taken from a sufficient number of spots to be considered fair average samples :—

ALTRINCHAM SEWAGE FARM.

Name of Fraction.	Surface soil per cent.			Subsoil per cent.		
	Not Ignited.	Ignited.	Difference.	Not Ignited.	Ignited.	Difference.
Fine 'Gravel" (above 2·0 m.m. diameter) -	6·34	4·85	1·49			
Coarse "Sand" (above 1·0 m.m. diameter) -	3·16	2·05	1·11			
Coarse "Sand" (above 0·5 m.m. diameter) -	3·65	2·37	1·28			
Medium "Sand" (above 0·25 m.m. diameter)	6·80	5·60	1·20			
Sand" (0·25 to 0·05 m.m. diameter) -	37·56	33·22	4·34			
"Silt' (0·05 to 0·01 m.m. diameter) - -	27·16	16·44	10·72			
"Dust" (from 0·01 m.m. downwards, which settles from water in 24 hours) - -	10·95	7·64	3·31			
"Clay" (*i.e.* the still finer residue precipitated from water by dilute nitric acid)	2·83	2·13	0·70			
Loss on ignition (separate determination) -		23·24				
	98·45	97·54	24·15			
Real specific gravity of soil dried at 110°C.	2·377					
Apparent specific gravity - - - -	0·858					
Number of particles in 1 gramme of the ignited soil (approximate) - - -	1,284,209,670					
Number of particles in 1 c.c. of the ignited soil (approximate) - - - - -	1,101,862,900					
Weight of water retained by 100 grammes of soil when fully drained - - -	66·2			45·7		
Parts per 100,000.						
Lime dissolved by water in 24 hours -	0·045			0·016		
Lime dissolved by water saturated with carbonic acid in 48 hours - -	0·197			0·068		

For a discussion of the figures given in this Table, *see* Section upon Soils, page 275.

Volume of Sewage per acre, &c.

The average dry weather flow of sewage is 800,000 gallons in 24 hours, but great fluctuations occur in the flow during wet weather, the combined sewerage system being in use. The population draining to the farm being 18,000, the dry weather flow works out to 44·4 gallons per head, and the number of persons per acre irrigated is 514. Mr. Kershaw says in his Report‡ that although "w.c.'s are used over the greater part of the town, there are a few privies, the contents of which are not dealt with at the sewage farm." These privies, however, are so few in number that they may be neglected. Much of this dry weather flow of 44·4 gallons per head consists of subsoil water leaking into the sewers.

There is but little subsoil water above the level of the drains at the farm itself.

As already stated, about half of the irrigable area is under sewage at a time, one acre thus treating 46,000 gallons of sewage or lagoon liquor. But again assuming, *for purposes of comparison*, that the entire irrigable area is under sewage continuously, *then each acre treats* 23,000 *gallons per* 24 *hours all the year round.* The farm thus deals with a large volume of a dilute sewage per acre, and also a large quantity in the aggregate of organic matter, although not so much as is treated at Cambridge; the analytical data do not allow of a more precise statement here.

Nature of Sewage (*Diagram No.* 10).

The Altrincham sewage may be taken as purely domestic, there being practically no trade refuse in it. It must, of course, not be forgotten that the sewage contains the runnings from streets, roofs and backyards during storms. The sewage is weak, and it arrives at the farm in a fairly fresh condition. No sets of hourly samples of it were taken, but only four chance samples of sewage and five of lagoon liquor (*), the latter being, if anything, the stronger. As has been stated in the Engineering Report‡, there is practically no tank settlement at the farm. Any calculations as regards percentage purification, therefore, which are made on the basis of these analyses must be very approximate indeed, and of doubtful value.

All those samples were drawn in April and May, 1900, and in the same months of 1901, the other arrangements not allowing of a visit at a different time of the year. The temperature of the sewages when drawn varied between 7·2° and 17·7° C. (45° and 64° F.), and that of the lagoon liquors between 8·3° and 17·2° C. (47° and 63° F.).

There was nothing unusual about the character of the sewages, the amounts of grey, brown or black suspended matter in them being moderate. No. 249 had a soapy smell. The three samples tested for reaction were alkaline. The lagoon liquors were turbid, had a sewage smell, and were also alkaline in reaction. Some of them were green from the presence of algæ.

Sewages and Lagoon Liquors together.

The following is a summary of the more important figures of analysis :—

	Average.
Total nitrogen—9 chance samples (2·06 to 5·01) - - - -	3·56
Ammoniacal nitrogen—9 chance samples (0·69 to 3·69) - -	2·29
Total organic nitrogen—9 chance samples (0·73 to 3·00) - - -	1·24
Albuminoid nitrogen—9 chance samples (0·20 to 1·14) - -	0·62
"*Oxygen absorbed*" *from permanganate in* 4 *hours at* 26·7° C. (80° F).—9 chance samples (2·29 to 6.98) - - - - -	5·22
Chlorine—9 chance samples (7·22 to 12·88) - - - -	9·43
Chlorine in water supply† - - - - - - - -	1·03
Chlorine in one sample of subsoil water (No. 78) - - - -	1·54
Solids in Suspension by Centrifuge (*Volumes*) (two sewages and three ponded liquors) (27 to 99) - - - - - -	72·0

* For an explanation of the terms "ponded" and "lagoon" liquors, see the Engineering Report.

† This is taken from an old analysis, kindly supplied to me, in which I am assuming that the various figures were given in grains per gallon.

‡ Part IV. Engineering and Practical Report.

Sample No. 68, though not included in the above nine samples, may also be referred to here. It was a storm water, drawn after the overflow had worked for 1½ hours. As will be seen by referring to the Tables of Analysis, it was a weak sewage, and was already putrid when received.

One or two points with reference to the above analyses may be referred to :—

It will be seen by looking at the curves that although the *chlorine* did not vary much in the four sewages, they were otherwise very uneven in composition, though in no case strong; the chlorine varied relatively much more in the five lagoon liquors, but the other constituents less. A glance at the *total nitrogen* curve in the lagoon liquors will show that it was a fairly constant quantity, the lagoons thus acting more or less as equalising besides as septic tanks; it will be noticed that these liquors contained no nitrite.

The average ratio between albuminoid nitrogen and "oxygen absorbed" in four hours varied in the four samples of sewage between 1 : 6·5 and 1 : 13·2, the average being 1 : 8·4; in the lagoon liquors the extremes were 1 : 5·1 and 1 : 15·2, and the average 1 : 9·5.

Excepting in No. 69, *the ratio between the organic nitrogen and "oxygen absorbed" in four hours* was very even in the lagoon liquors, the average ratio for the five samples being 1 : 5·3. In the four samples of sewage this ratio was very uneven. In the five samples tested, the estimation of organic nitrogen by the two different *Kjeldahl* methods agreed very well.

Effluents. (*Diagram No.* 11.)

As stated already, these are *percolation or filtration effluents* from one treatment of settled (?) sewage or lagoon liquor through an average depth of 3ft. 9in. of the composite soil previously described.

Sixteen chance samples of effluent were examined, five of them in duplicate after jointing or incubation, making twenty-one analyses in all. They are arranged continuously on the sheet of curves in the following order :—

(a) General effluents (1).

(b) Effluents from mangolds (3).

(c) Effluents from osier beds (5).

(d) Effluents from uncropped arable land (7).

Mr. Kershaw's Notes on Samples should be referred to for further details of each of these.*

These were all drawn in the months of April and May, 1900 and 1901, their temperatures varying between the comparatively narrow limits of 5·5° and 11·1° C. (42° and 52° F). Speaking generally, the effluents, which were dilute, did not vary a great deal in strength.

The following Table shows some of the more important average analytical figures from the examination of 14 to 18 effluents, details being given in the annexed Tables of Analysis and Curves :—

	Average.
Total nitrogen (1·36 to 4·99)	2·22
Ammoniacal nitrogen (0·65 to 1·87)	1·23
Albuminoid nitrogen (0·07 to 0·25)	0·13
Total organic nitrogen (0·10 (?) to 0·45)	0·26
"Oxygen absorbed" from permanganate at 26·7° C. (80° F.) *in* 4 *hours* (0·92 to 2·65)	1·75
Incubator test (as judged by smell)	81 per cent. passed (16 samples tested).

* Part IV.: Engineering and Practical Report.

Those effluents contained varying amounts of red-brown flocculent matter, no doubt mainly ferric hydroxide or basic carbonate, which gave to many of them a turbid appearance and a deep brown colour. Nos. 267 and 274 showed this more particularly; in No. 66, it is noted that the colour was due to iron and not to peaty matter, and this no doubt applies to the others also. After being filtered, some of the effluents were just tinged, but others were still very brown. They had either no smell at all or an iron smell; in one or two instances the odour was so strong as to be suspicious, but the presence of so much iron necessarily made the characterisation of the smell more difficult than usual (*cf.* No. 251B.). There was much lime and much sulphate in solution, and also—as stated above—very considerable quantities of iron, mostly in the state of ferric hydroxide, partly in suspension and partly in solution; in the worse effluents some ferrous iron was also present. Strictly speaking, they would have been the better for being strained or settled before being run into a brook (*cf.* remarks on the Aldershot Camp farm effluents). Besides affecting the smell, the presence of so much iron accounts for the comparatively small quantity of dissolved oxygen found in those effluents; under ordinary conditions effluents of this class ought to have contained more oxygen, although, on the other hand, it must be remembered that the Altrincham effluents come from a weak sewage, and would therefore tend to take up oxygen more rapidly than effluents of *apparently* the same chemical composition derived from a strong sewage. The dissolved oxygen test is therefore to a great extent discounted here.*

The analytical tables and curves show that, with the exception of Nos. 66 and 252, both of which contained a large reserve of nitrate evidently washed out of a mangold plot, the effluents were fairly even in composition, though they gradually became slightly stronger towards the end of the second period of observation.

The small amounts of *dissolved oxygen* present when the samples were analysed (maximum = 1·3 c.c.) has been already referred to, and an explanation offered.* Out of five estimations made of the dissolved oxygen at the time of drawing, the maximum (3·0 c.c.) was found in No. 251. For percolation effluents the quantity of dissolved carbonic acid was not very great in the five samples tested for this; this would arise in the first instance from the original sewage being rather weak, and in the second, possibly, from some of the carbonic acid being taken up by the iron in the soil.

The *ammoniacal nitrogen* in sixteen effluents (including four percolation effluents direct from the lagoons) varied between 0·65 and 1·87, the average figure being 1·23; thus rather more than half of the total nitrogen in those effluents consisted of ammoniacal nitrogen.

The *albuminoid nitrogen* in the sixteen samples varied between 0·07 and 0·25, the average being 0·13. All of the nine, excepting possibly No. 248, kept on incubation.

The figures for "*oxygen absorbed*" varied between 0·92 and 2·65, average 1·75. All of the five, excepting possibly No. 70, kept upon incubation.

Mr. Scudder's incubator test† by permanganate and the incubation test by smell agreed on the whole. Three of the sixteen effluents went distinctly putrid on incubation, while some others were doubtful.

The *total nitrogen* in fourteen effluents varied only between 1·36 and 2·23, a low figure. In samples Nos. 66 and 252 it went up to 4·97 and 4·99. The average for the whole sixteen was 2·22.

The *total organic nitrogen* was not as a rule large. Speaking generally, it was just twice the albuminoid nitrogen, but the two curves bear no relation to one

---

* *Note.*—The difficulty of estimating oxygen in brown-coloured samples by the copper chloride method has been referred to in the Report on Methods of Chemical Analysis (Part V.). But even allowing for this, it would not apply to the earlier samples, which were boiled out.

† In one or two samples, where nitrite was not determined after incubation, it was assumed to be no greater than before incubation.

another. The determination of organic nitrogen by Kjeldahl *without* reduction came out badly in the case of these effluents; by the method *with* reduction it was moderately satisfactory, but one cannot say more.

Only comparatively few of these effluents contained *nitrous nitrogen*, in amounts varying between 0·03 and 0·11 parts per 100,000.

The *nitric nitrogen* (again excepting samples 66 and 252) never reached 1 part per 100,000, and in the larger number of the samples was decidedly low; there was, in fact, too little reserve of nitrate in a considerable number of the samples.

The ratio of oxidised to unoxidised nitrogen (taking the unoxidised = 1) varied between 0·0 and 2·7, the average for the sixteen effluents being 0·6; or, if we leave out of account the two highly nitrated ones, Nos. 66 and 252, the average for fourteen effluents is 0·3 : 1. The "safety limit" ratio appears to lie somewhere between 0·3 and 0·5, or perhaps one ought to say at 0·5 : 1.

The ratio of oxidised to albuminoid nitrogen (taking the albuminoid = 1) varied between 0 and 34·1, the average being 6·7. Leaving out the two highly oxidised effluents, the average for the 14 remaining is 3·1 : 1. The "safety limit" ratio is evidently somewhere about 3 : 1 for these effluents, although three samples with a lower ratio kept sweet on incubation; while, on the other hand, one with a slightly higher ratio was doubtful after being incubated.

There is not much agreement between the albuminoid nitrogen and "oxygen absorbed" curves; any ferrous iron present would of course make itself felt in the latter. Speaking generally, the "oxygen absorbed" and nitrate curves are inversely as one another.

The following Table shows the effect of incubation upon a few of the Altrincham effluents as regards the ammoniacal and the nitric nitrogen :—

Number of Sample	72	76	248	250	251B	255
Ammoniacal Nitrogen :						
(*a*) Before incubation	1·24	0·71	1·58	1·52	1·53	1·55
(*b*) After ,,	1·35	0·71	1·53	1·61	1·43	1·47
Nitric and Nitrous Nitrogen together :						
(*a*) Before incubation	0·58	0·55	0·33	0·44	0·29	0·21
(*b*) After ,,	0·29	0·37	0·03	0·12	0·0	0·02

These few results are in some respects contradictory, but they show at least that, when nitrate was present in moderate quantity (say, 0·4 to 0·6 parts of nitric nitrogen per 100,000), it did not suffer much decrease upon incubation.

Conclusion.—As regards the treatment of large volumes of weak domestic sewage, Cambridge and Altrincham are more or less parallel; but in the nature of the soil and subsoil and in the depth to the drains the two differ materially. The Altrincham effluents were fairly satisfactory on the whole, but the nitrification was not carried quite far enough in relation to the total nitrogenous matter present. The effluents from the uncropped arable land were the least nitrated. The results showed that at the time of our observations the land was getting rather too much to do, but they also showed that it was capable of turning out good effluents. It should not be forgotten, in connection with this criticism, that at Altrincham some (though not much) storm water is also treated, and that the whole of the sludge from tank or lagoon is dug into the soil. The relative number of particles in unit weight of the ignited soil is 157 (Nottingham soil = 100), and in unit volume 100; but the presence of the very large proportion of peaty matter in the Altrincham soil makes this comparison of little value. The rate of filtration at Altrincham is probably fairly rapid. (Compare Section on Soils and *Conclusions.*)

Percentage purification as calculated upon the albuminoid nitrogen and "oxygen absorbed" in four hours.

It seems hardly worth while to give this calculation here, as it must necessarily be of little value, seeing that only four chance samples of sewage and five of lagoon liquor were examined. So the figures must be taken as being very approximate indeed.

(1) *Albuminoid Nitrogen.* Average.

9 chance samples of settled sewage and lagoon liquor gave (0·20 to 1·14) - - - - - - - - - - 0·62

16 samples of effluent gave (0·07 to 0·25) - - - - - 0·13

The percentage purification, therefore, was 79 per cent.

(2) *Oxygen absorbed.*

9 chance samples of sewage and lagoon liquor gave (2·29 to 6·98) - - - - - - - - - 5·22

16 chance samples of effluent gave (0·92 to 2·65) * - - - 1·75

Percentage purification, 66·5 per cent.

Comparison of the total nitrogen in the settled sewages and lagoon liquors and in the Effluents.

For the same reasons that have just been given, the figures regarding this are of very doubtful value.

The average total nitrogen in 9 chance samples of sewage and lagoon liquor was (2·06 to 5·01) - - - - - - - - - - - - 3·56

The average total nitrogen in 16 effluents was (1·36 to 2·23, with two effluents containing 4·97 and 4·99) - - - - - - - - - 2·22

Allowing nothing for evaporation on the one hand, or for farm subsoil water on the other, about 40 per cent. of the total nitrogen going on to the land in the sewage and ponded liquors disappeared, *i.e.* was partly taken up by plants and partly lost, no doubt, as gaseous nitrogen.

Storm Water.

Only one sample of storm water was received from Altrincham, drawn on April 29th, 1900, after the overflow had been working for one and a-half hours. This was a dilute sewage and putrid when received, though only a small quantity of black deposit was present in it. It gave the figures:—

·48 albuminoid nitrogen;

·93 total organic nitrogen;

and 6·13 "oxygen absorbed" in 4 hours.

Subsoil Water.

Only one sample of this (No. 78) was examined. Mr. Kershaw gives it in his Notes on Samples as drawn from a trench on the farm sunk 3ft. 6in. deep, about 150 yards from the part sewaged, and about 100 yards from a large fish refuse heap. The water percolated into the trench through a stratum of very fine white sand.

* In one case, at all events, this figure was raised by the presence of ferrous iron.

A reference to the analytical figures shows that this sample (after decantation from its mud) might be classed as a moderately good effluent but not as a water. The high "oxygen absorbed" figure was to some extent due to the ferrous iron present. It will be noticed that this water, coming as it did from peat, remained distinctly acid after being boiled. The chlorine in it was greater than that in the town's water supply. The water was still brown when analysed, the turbidity being caused by iron together with some peaty matter.

Water from the Sinderland Brook, with and without admixed effluent from the Altrincham farm. (*Diagram No.* 12.)

As stated in the Engineering Report, this brook is polluted before it passes the farm. Mr. Kershaw says :—"This brook is frequently polluted by tan refuse. A large storm overflow culvert (from another district) also discharges into the stream a little distance above the Altrincham sewage farm. The ratio of effluent to brook water, normally, is approximately as 1 : 3."

Six samples were examined chemically, one of them in duplicate after incubation, making seven analyses altogether. Of these, Nos. 71, 251A and 274A were drawn above the effluent outfall, and the others below it.

Leaving out of account No. 274A, which was drawn above the effluent outfall when some tan liquor was passing down the stream, and which was thus very badly polluted (it smelt of sulphuretted hydrogen after incubation), the other samples all contained considerable quantities of flocculent suspended matter or sediment, though, after filtration, they were either almost colourless or of a slight brown tint. They had a clean smell, were alkaline or slightly alkaline in reaction, and those tested were found to contain much lime and much sulphate in solution, and also a very considerable amount of ferric iron—mostly in suspension.

A reference to the Tables of Analysis and the Curves shows that this brook was not in a satisfactory state. Although only the one sample went bad upon incubation, the total nitrogen present (in the four samples examined for this) was large, and the "oxygen absorbed" figures high. In only one case (No. 251A) was the amount of dissolved oxygen at all great when the sample came to be analysed. It is curious that No. 276A should have withstood incubation, both its dissolved oxygen and nitrate being exhausted thereby. Samples Nos. 71 (above outfall), 73 (below), and 74 (still further below) are comparable ; though the last two are not quite so good as the first, there is not much difference between them. It would be rather hard to say definitely what effect the Altrincham farm effluent itself would have upon this brook.

It should be noted here that the method of determining organic nitrogen by Kjeldahl *without* reduction answered better than the method *with* reduction for these brook waters.

ALTRINCHAM SEWAGE FARM.

TABLES OF ANALYSIS.

INDEX.

	PAGE.
Sewage, Lagoon Liquors, Effluent and Storm Water, Nos. 64, 65, 66, 68, 69	56
Sewage and Effluents, Nos. 70, 72, 75, 76, 77	57
Sewage and Effluents, Nos. 248, 249, 250	58
Effluents, Nos. 250, 251, 251B, 252, 253, 254	59
Sewage, Lagoon Liquor and Effluent, Nos. 255, 264, 265	60
Lagoon Liquors and Effluents, Nos 266, 267, 274, 275, 276	61
Brook water above and below Effluent outfall:—	
Nos. 71, 73, 74	62
Nos. 251A, 274A, 276A	63
Subsoil water, No. 78	63

ALTRINCHAM SEWAGE FARM, 1900.

Sewage, Lagoon Liquors and Effluents.

No. of Sample	64	65	66	68	69
Nature of Sample	Settled Sewage from Catchpit.	*Ponded Liquor from Lagoon (sludge settled).	Final Effluent after passing over one acre of land sown with mangolds and ridged.	Storm Water after overflow had worked for 1½ hours.	Ponded Liquor.
Drawn	Thursday, 26th April 1900, 10.15 a.m.	Thursday, 26th April 1900, 11.30 a.m.	Thursday, 26th April 1900, 12.15 noon.	Sunday, 29th April 1900, 2.0 p.m.	Monday, 30th April 1900, 11.50 a.m.
Temperature of sample	9·4° C. (49° F.)	8·3° C. (47° F.)	8·3° C. (47° F.)	10·6° C. (51° F.)	13·3° C. (56° F.)
Temperature of air	—	—	—	—	—
If jointed or incubated	—	—	—	—	—
Analysed	27th April 1900.	27th April 1900.	27th April 1900	1st May 1900	1st May 1900.
Parts per 100,000 by weight.					
Ammoniacal nitrogen—					
(a) by direct Nesslerization	Turbid.	Turbid.	Turbid.	2·12	Turbid.
(b) by distillation	0·97	2·89	1·25	2·10	1·07
Albuminoid nitrogen	0·41	1·14	0·10	0·48	0·85
Nitrous "	0·18	None.	0·11	None.	None.
Nitric "	Not done.	None.	3·30	None.	Not done.
Total nitrogen by Kjeldahl, *with* reduction (after correction for nitrite)	2·06	4·07	4·99	3·03	4·08
Blank	(0·32 in 3·16)	(0·32 in 6·23)	(0·19 in 7·34)	(0·19 in 4·59)	(0·32 in 6·25)
Correction for nitrite	0·10	None.	0·06	None.	None.
"X" nitrogen	0·50	0·03	0·23	0·45	2·45
Organic nitrogen by Kjeldahl, *with* reduction	0·91	1·17	0·33	0·93	3·00
Organic nitrogen by Kjeldahl, *without* reduction :—					
(a) Taking ammonia by direct Nesslerization	—	—	—	1·05	—
(b) Taking ammonia by distillation	0·72	1·09	None (– 0·21)	1·07	3·30
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once*	0·62	1·40	0·49	1·41	1·93
" " *after 4 hours*	2·29	5·84	1·61	6·13	6·98
Oxygen absorbed from permanganate by sample incubated for 5 days at 26·7° C. (80° F.); *at once*	—	5·32	0·12	—	—
" " *after 4 hours*	—	7·63	1·35	—	—
Smell after incubation	—	Putrid to begin with.	Slight earthy.	—	—
Chlorine	8·32	10·72	8·06	6·50	8·48
Gases; Parts per 1,000 by volume.					
Carbon dioxide (free)	—	40·18	91·37	—	—
Oxygen (boiled out)	—	0·17 (?)	0·96	—	—
Nitrogen	—	18·76	18·31	—	—
			It is no doubt the iron present which has almost exhausted the dissolved oxygen. A transferred sample was boiled out.		
Remarks	A weak sample with a very trifling grey deposit. Sewage smell.	This sample was grey and very turbid, with a strong sewage smell. Somewhat slowly alkaline. There had been 8° F. of frost at Altrincham the night before. Much lime in solution, and much sulphate.	Excessively brown, with a moderate amount red-brown flocculent matter. The filtered liquid was slightly brown. Fishy and iron smell. Slightly acid. Alkaline after boiling.	This sample was sent by parcel post in a corked wine bottle, in the neck of which there was a small air bubble. Small quantity of black deposit. Putrid smell.	Very turbid from suspended matter, apparently vegetable. Sewage smell. Alkaline.
			A great deal of lime and also of sulphate in solution, and much ferric iron both in solution and in suspension. The colour was due to iron and *not* to peaty matter.		

*Note.—A ponded liquor and a Lagoon liquor mean the same thing.

ALTRINCHAM SEWAGE FARM, 1900.

Sewage and Effluents.

70	72	72	75	76	76	77
CORRESPONDING FINAL EFFLUENT after going over ridged arable land sown with mangolds.	GENERAL EFFLUENT from main outfalls.	DUPLICATE SAMPLE.	SETTLED NIGHT SEWAGE from tank.	FINAL EFFLUENT from osier beds on peat land. From night sewage.	DUPLICATE SAMPLE.	FINAL EFFLUENT from same source as No. 76.
Monday, 30th April 1900, 1.15 p.m.	Monday, 7th May 1900, 11.50 a.m.	—	Tuesday, 15th May 1900, 11.30 a.m.	Tuesday, 15th May 1900, 1 p.m.	—	Wednesday, 16th May 1900, 11.50 a.m.
8·9° C. (48° F.)	11·1° C. (52° F.)	—	10·0° C. (50° F.).	8·9° C. (48° F.)	—	9·4° C. (49° F.).
—	—	—	—	—	—	—
—	—	Jointed on 8th May.	—	—	Jointed on 16th May.	—
2nd May 1900.	8th May 1900.	18th May 1900.	16th May 1900.	16th May 1900.	18th June 1900.	17th May 1900.
Turbid.	Turbid.	Filtered through paper. Turbid.	4·28 (approx.; a little turbid).	Turbid.	Turbid.	Turbid.
0·93	1·24	1·35 1·34	3·69	0·71	0·71	0·76
0·18	0·25	0·25 0·14	0·98	0·21	0·16	0·11
None.	Slight trace.	None.	None.	None.	Very slight trace.	None.
0·66	0·58	0·29	Not done.	0·55	0·37	0·20
2·03	2·16	1·87	5·01	1·36	1·15	1·20
(0·19 in 3·14)	(0·19 in 3·33)	(0·19 in 2·91)	(0·19 in 3·83)	(0·19 in 2·17)	(0·19 in 1·86)	(0·19 in 1·96)
None.	None.	None.	None.	None.	None.	None.
0·26	0·09	None (— 0·02).	0·34	— 0·11 (?)	None (—·09)	0·15
0·42	0·34	0·25	1·32	0·21 (?)	0·16 (?)	0·26
—	—	—	—	—	—	—
0·16	0·04	0·13	1·42	0·15	0·14	0·19
0·11	0·70	0·52	0·91	0·41	0·35	0·41
1·23	2·35	2·03	7·98	1·59	1·17	1·76
0·36	1·49 } 6 days.	0·64 } 6 days.	—	0·41	0·23 } 8 days.	0·40
1·26	1·96	1·95	—	1·29	1·11	1·64
Sweet (?).	Sweet.	Sweet.	—	Slight earthy smell.	Sweet; Earthy.	Sweet.
9·12	8·28	—	8·62	8·96	—	9·00
64·29	58·49	Gases	—	65·17	66·24	72·56
0·88	0·67	Lost.	—	0·60	0·04	0·26
17·47 The iron has no doubt helped to exhaust the oxygen.	16·60 Iron here again.	—	—	17·69	17·10 There was a moderate-sized bubble of gas at the top of the bottle.	17·75
Yellowish, though far less coloured than No. 66. The filtered liquid had but a tinge of colour. A little red-brown flocculent matter. Reaction about neutral, but alkaline after boiling. Very considerable amount of lime in solution; much sulphate; very little ferric iron.	Very considerable amount of brown-red flocculent matter and the paper filtrate was distinctly brown (more so than before). Reaction slightly acid, but alkaline on boiling. Fishy - earthy smell. Much lime and sulphate in solution, also a good deal of ferric iron in semi-solution or solution.	The red flocculent matter had now aggregated. The paper-filtered liquid had still a very distinct brown tinge, and still contained an appreciable amount of iron. Smell quite clean, but chalybeate. Reaction slightly acid in the cold (alkaline on boiling).	This sample contained only a slight grey and brown deposit. Sewage smell. Alkaline. It is a weak sample.	Much brown suspended matter. The paper-filtered liquid had a slight but distinct brown tinge, and was almost clear. Somewhat peculiar smell (iron?). Decidedly acid in the cold, but alkaline on boiling. Much lime and sulphate in solution; also a considerable amount of ferric hydroxide (mostly in suspension). The sewage takes a very long time to pass off from these osier beds.	This sample had now a clean smell—a kind of seaweed smell. Reaction about neutral; it became distinctly alkaline on boiling.	This sample (which came in a bottle with badly fitting stopper) closely resembled No. 76, *i.e.*, it contained a considerable amount of red flocculent matter. Small bubble of air at top of bottle. The filtered liquid was distinctly brown. Reaction tending to acid (alkaline on boiling). Smell fishy or iron (?). Considerable lime. Much sulphate. Much ferric iron, mostly in suspension.

ALTRINCHAM SEWAGE FARM, 1901.

Sewage with Effluents.

No. of Sample	248	248	249	250
Nature of Sample	Final Effluent (iron and sewage smell when drawn).	Medium Sized Duplicate.	Settled Sewage (very dilute).	Final Effluent corresponding to sewage No. 249. (Sewage and iron smell).
Drawn	Tuesday, 16th April 1901, 11.10 a.m.	—	Wednesday, 17th April 1901, 10.45 a.m.	Wednesday, 17th April 1901, 12 noon,
Temperature of sample	5·6° C. (42° F.)	—	7·2° C. (45° F.)	6·7° C. (44° F.)
Temperature of air	6·1° C. (43° F.)	—	8·3° C. (47° F.)	9·4° C. (49° F.)
If jointed or incubated	—	Incubated 17th April. *Not* jointed.	—	—
Analysed	17th April 1901.	22nd April 1901.	18th April 1901.	18th April 1901.
Parts per 100,000 *by weight.*				
Ammoniacal nitrogen—				
(a) by direct Nesslerization	Turbid.	—	—	Turbid.
(b) by distillation	1·58	1·53	0·69	1·52
Albuminoid nitrogen	0·11	0·14	0·20	0·10
Nitrous "	0·03	None	0·09	0·07
Nitric "	0·30	0·03	Not done. (Should have been)	0·37
Total nitrogen by Kjeldahl, *with* reduction (no correction for nitrite)	1·99	1·75	2·22	2·13. This estimation begun 25th April.
Blank	(0·16 in 3·05)	(0·16 in 2·07)	(0·19 in 3·81)	(0·16 in 3·25)
"X" nitrogen	None (−·03)	0·05	1·24 (?)	0·07
Organic nitrogen by Kjeldahl, *with* reduction	0·11	0·19	1·44 (?)	0·17
Organic nitrogen by Kjeldahl, *without* reduction:				
Taking ammonia by distillation	0·17	—	—	0·18
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once*	0·54	0·40	1·02	0·46
" " " *after four hours*	2·00	—	2·65	1·91
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once*	0·40	—	—	0·40
" " " *after four hours*	1·79	—	—	1·83
Smell after incubation	Suspicious (Sewage and iron?). No nitrite.	—	—	Strong, earthy. Nitrite nitrogen fully 0·07.
Chlorine	7·96	—	7·22	7·66
Parts per 100,000 *by volume.*				
Solids by centrifuge	—	—	79·0	—
Gases: parts per 1,000 *by volume.*				
Oxygen (by cuprous chloride):				
(a) When sample was drawn	—	—	—	1·0
(b) " " " analysed	None	—	—	None.
Remarks	This sample had a deep yellow colour, with flocculent reddish-brown sediment. Suspicious smell. Very slightly acid from carbonic acid; alkaline on boiling.	After incubation this sample had a deep yellow colour, with considerable brown sediment. Smell either of sewage or of sewage and iron. Much ferric, but no ferrous iron.	This was a slightly brown turbid liquid, with a considerable amount of dark grey-brown sediment. Soapy smell. Alkaline. I should think that this sample probably contained some nitrate, so that the figures for the "X" nitrogen and the organic nitrogen are most likely wrong, *i.e.*, much too high.	This was of a deep yellow colour, with reddish-brown suspended matter. Strong iron smell. Faintly alkaline.
	This sample is apparently on the border line. The presence of so much iron has apparently affected the smell.			

ALTRINCHAM SEWAGE FARM, 1901.

Effluents.

250	251	251B	251B	252	253	254
SMALL DUPLICATE.	FINAL EFFLUENT from osier beds treating crude sewage.	FINAL EFFLUENT (Iron smell), from same source as No. 250.	SMALL DUPLICATE.	FINAL EFFLUENT from mangold plot. Plants still growing.	FINAL EFFLUENT from osier beds (greenish yellow).	FINAL EFFLUENT from osier beds treating crude sewage.
	Wed., 17th April 1901, 12.30 noon.	Friday, 19th April 1901, 11.15 a.m.	—	Mon., 22nd April 1901, 11.10 a.m.	Mon., 22nd April 1901, 11.20 a.m.	Mon., 22nd April 1901, 11.45 a.m.
	6·7° C. (44° F.)	7·8° C. (46° F.)	—	8·9° C. (48° F.)	8·9° C. (48° F.)	7·8° C. (46° F.
	10° C. (50° F.)	13·3° C. (56° F.)	—	23·3° C. (74° F.)	23·3° C. (74° F.)	23·9° C. (75° F.)
ointed and incu-ated 18th April.	—	—	Jointed and in-cubated 20th April.	—	—	—
9th April 1901.	19th April 1901.	20th April 1901.	29th April 1901.	23rd April 1901.	24th April 1901.	24th April 1901.
—	—	—	—	—	—	Turbid.
1·61	0·65	1·53	1·43	0·86	(A) 0·98 (B) 1·09	0·77
0·09	0·08	0·16	0·12	0·12	Alk. Perm. 20 c.c. 0·114; 25 c.c. 0·12	0 07
0·03	None.	0·05	Trace.	0·09	Trace.	None.
0·09	0·82	0·24	None.	3·57	0·28	0·47
—	1·59	2·23	—	4·97	1·53	1·39
—	(0·19 in 2·79)	(0·31 in 3·96)	—	(0·31 in 8·45)	(0·31 in 2·81)	(0·16 in 2·18)
—	0·04	0·25	—	0·33	0·16 0·04	0·08
—	0·12	0·41	—	0·45	0·27 0·15	0·15
—	—	—	—	—	—	0·37 very turbid; approx.
0·45	0·22	0·48	0·47	0·34	0·47	0·19
—	1·24 (5 hours)	1·89	—	0·92	1·28	1·12
—	0·23	0·39	—	0·31	0·19	0·15
—	1·00	1·68	—	1·06	1·63	Lost.
Doubtful.	None. No nitrite.	Strong earthy.	No smell.	No smell. 0·13 Nitrite nitrogen.	No smell. About 0·01 Nitrite nitrogen.	Sweet. Probably no nitrite.
—	7·00	8·40	—	7·66	8·36	7·20
—	Very small amount	—	—	29·0 (1½ minutes)	—	—
—	3·0	None.	—	—	—	—
—	0·5	None.	—	1·0 approx.	None.	1·3
Moderate amount of light-brown sediment. The filtered liquid was yellow. This sample is apparently just within the border line.	Brown clear liquid with not very much sediment, which was aggregated in red-brown particles. No smell. Alkaline.	Very brown clear liquid with a small amount of sediment. Rather unpleasant, putrid (?) smell. Alkaline.	After incubation, this liquid had no smell. This is a very interesting case. Evidently a border line effluent.	Fairly clear brown liquid, with a moderate amount of light brown sediment (aggregated). No smell. Alkaline. The large amount of nitrate, coming away from ground on which mangolds had been planted, is worthy of note.	Very brown and slightly turbid liquid; clear and rather less coloured after filtering. Metallic smell. Alkaline.	Yellow even when filtered, with considerable flocculent reddish-brown sediment Slight iron smell. Faintly alkaline.

ALTRINCHAM SEWAGE FARM, 1901.

Sewage, Lagoon Liquor and Effluents.

No. of Sample	255	255	264	265	265
Nature of Sample	Percolation effluent from lagoon.	Small Duplicate	Settled Sewage prior to going into lagoon.	Liquor from first lagoon.	Small Duplicate.
Drawn	Monday, 22nd April 1901, 12.0 noon.	—	Tuesday, 30th April 1901, 12.0 noon.	30th April 1901, 12.30 noon.	—
Temperature of sample	10° C. (50°F.)	—	17·7° C. (64° F.)	17·2° C. (63° F.)	—
Temperature of air	23·9° C. (75° F.)	—	19·4° C. (67° F.)	19·4° C. (67° F.)	—
If jointed or incubated	—	Jointed and incubated 23rd April 30th April 1901.	—	—	Jointed and incubated 1st May. Opened 5th May.
Analysed	23rd April 1901.		1st May 1901.	1st May 1901.	
Parts per 100,000 *by weight.*					
Ammoniacal nitrogen:					
(a) By direct Nesslerization	Turbid.	—	—	—	—
(b) By distillation	1·55	1·47	3·30 (?)	2·17	—
Albuminoid nitrogen	0·15	0·11	0·73	0·37	—
Nitrous ,,	0·03	None	None.	None or trace.	—
Nitric ,,	0·18	0·02	Not done.	Not done.	—
Total nitrogen by Kjeldahl, *with* reduction	2·06	—	4·01 (?)	2·87	—
Blank	(0·16 in 3·15)	—	(0·22 in 6·04)	(0·33 in 5·02)	—
"X" nitrogen	0·15	—	None (?)	0·33	—
Organic nitrogen by Kjeldahl, *with* reduction	0·30	—	0·73 (?)	0·70	—
Organic nitrogen by Kjeldahl, *without* reduction:					
Taking ammonia by distillation	0·12 {v. approx. v. turbid}	—	0·84	—	—
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once*	0·36	0·43	1·12	1·34	—
,, ,, ,, *after four hours*	1·98	—	4·74	4·27	—
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once*	0·42 } 6 days	—	—	—	—
,, ,, ,, *after four hours*	1·89 } 6 days	—	—	—	—
Smell after incubation	Suspicious. No nitrite.	Very strong and suspicious.	—	—	—
Chlorine	8·50	—	8·30	10·18	—
Parts per 100,000 *by volume.*					
Solids by centrifuge	—	—	99·0 (1 minute) May 11th.	57·0 (1 minute).	—
Gases; Parts per 1,000 *by volume.*					
Oxygen (by cuprous chloride):					
(a) When sample was drawn	—	—	—	—	—
(b) ,, ,, analysed	None	—	—	—	—
Remarks	This bottle was sent with a cork in it. The liquid had a deep yellow or brown tinge; yellow after filtering. Slightly turbid, with reddish-brown suspended matter. Strong iron smell. Acid from carbonic acid.	Brown coloured, with a small quantity of light brown sediment.	Turbid, with a small amount of black and brown sediment. Alkaline.	Turbid, slightly brown liquid with a sewage smell. Alkaline. This is a dilute sewage. This contained a green weed which rapidly attached itself to the side of the bottle next to the light.	As was to be expected, this was black and very putrid when opened.

ALTRINCHAM SEWAGE FARM, 1901.

Lagoon Liquors and Effluents.

266 ME LIQUOR AS No. 265.	266 SMALL DUPLICATE.	267 FINAL EFFLUENT from lagoons (*i.e.*, after percolation.)	274 FINAL EFFLUENT after passing through Lagoon (percolation.)	275 SURFACE LIQUOR from last lagoon.	276 FINAL FILTRATION EFFLUENT corresponding to No. 275.	276 SMALL DUPLICATE.
esday, 30th April 1901, 1 p.m.	——	Wednesday, 1st May 1901, 10.45 a.m.	Tuesday, 7th May 1901, 2.30 p.m.	Wednesday, 8th May 1901, 11.30 a.m.	Wednesday, 8th May 1901, 12.30 noon.	
6·7° C. (62° F.)	——	10·0° C. (50° F.)	11·1° C. (52° F.)	10·0° C. (50° F.)	10·0° C. (50° F.)	
0·0° C. (68° F.)	——	15·6° C. (60° F.)	11·7° C. (53° F.)	13·9° C. (57° F.)	12·8° C. (55° F.)	
——	Jointed and incubated 1st May. Opened 5th May.	——	——	——	——	Jointed and incubated 9th May. Opened 30th May 1901.
st May 1901.		2nd May 1901.	9th May 1901.	9th May 1901.	9th May 1901.	
3·95 approx. poilt by colour).	——	Turbid.	——	——	——	——
2·66	——	1·69	1.87	3·19	1·71	——
0·50	——	0·15	0·13	0·42	0·10	——
None.	——	None.	None.	Not done { These should have been tested for. }	None.	——
Not done.	——	None.	0·06		0·19	——
3·47	——	2·06	(a) 1·97 May 16. (b) 1·94 May 29.	4·27	(a) 1·92 May 9. (b) 1·86 May 18.	——
(0·22 in 5·25)	——	(0·22 in 3·21)	(0·22 in 3·08 and in 3·03)	(0·33 in 7·31)	(0·33 in 3·47 and in 3·36)	——
0·31	——	0·22	None. None.	0·66	None (?) (−0·11)	——
0·81	——	0·37	0·13 0·13	1·08	0·10 (?)	——
o turbid to read.	——	0·26 { v. approx. v. turbid. }	——	——	——	——
1·30	——	0·61	0·64	1·87	0·89	——
5 80	——	2·22	2·65	6·39	2·19	——
——	——	0·85	1·03	——	0·79	——
——	——	2·53	2·83	——	2·50	——
——	——	Putrid.	Putrid.	——	Rather putrid; no nitrite.	——
10·14	——	10·02	9·98	12·88	10·54	——
98·0 (1 minute.)	——	91·0 (probably 1 min.) 16th May.	99·0 (1 minute.)	27·0 (1 minute.)	Not enough sediment.	——
——	——	——	1·0	——	0·5	——
——	——	None.	None.	——	None.	——
reenish yellow iquid with a ittle suspended natter. Same reen weed as in 265. Sewage mell. Alkaline. This is a slightly tronger lagoon iquor than No. 265.	Blackened, and smelling even more strongly putrid than No. 265. Very small (?) amount of light brown sediment. Acid until boiled, and then alkaline. Strong smell, but not putrid. A considerable amount of lime in solution, and a moderate amount of sulphate. Much iron, both ferrous and ferric.	Deep brown colour from hydrated oxide of iron (the filtered liquid was yellow).	Deep yellow-brown, even when filtered. Small amount of reddish-brown sediment. Strong, but not putrid smell. Alkaline. A trace of ferrous and a good deal of ferric iron.	Brown, very turbid liquid, but not much sediment. Sewage smell. This is a weak sewage.	Very brown clear liquid with practically no sediment. Fishy smell.	When opened this was blackened, with considerable black deposit. Not analysed.

ALTRINCHAM SEWAGE FARM, 1900–1.

Brook Water alone and admixed with Effluent.

No. of Sample	71	73	74
Nature of Sample	Sinderland Brook Water.	Brook Water, containing effluent. Drawn 175 yards below last main effluent outfall.	Brook Water, containing effluent. Drawn 250 yards below main effluent outfall.
Drawn	Tuesday, 7th May 1900, 11.45, a.m.	7th May 1900, 12.5 noon.	7th May 1900, 12.15 noon.
Temperature of sample	11·1° C. (52° F.)	11·1° C. (52° F.)	11·1° C. (52° F.)
Temperature of air	——	——	——
If jointed or incubated	——	——	——
Analysed	11th May 1900.	9th May 1900.	10th May 1900.
Parts per 100,000 *by weight.*			
Ammoniacal nitrogen—			
(a) by direct Nesslerization	Turbid.	Turbid.	Turbid.
(b) by distillation	0·21	0·35	0·35
Albuminoid nitrogen	0·12	0·14	0·11
Nitrous "	0·02	Trace.	0·01
Nitric "	0·27	0·27	0·32
Total nitrogen by Kjeldahl, *with* reduction (after correction for nitrite)	0·52	0·70	0·75
Blank	(0·19 in 0·25)	(0·19 in 1·20)	(0·19 in 1·27)
Correction for nitrite	+0·01	None.	+0·01
"X" nitrogen	None (–·09 ?)	None (–·06)	None (–·04)
Organic nitrogen by Kjeldahl, *with* reduction	0·12	0·14 ?	0·11
Organic nitrogen by Kjeldahl, *without* reduction :— Taking ammonia by distillation	0·15	0·20	0·17
Oxygen absorbed from permanganate at 26·7° C. (80° F.) ; *at once*	0·20	0·15	0·29
" " *after 4 hours*	1·05	1·17	1·17
Oxygen absorbed from permanganate by sample incubated for 5 days at 26·7° C. (80° F.) ; *at once*	0·18	0·29	0·30
" " *after 4 hours*	1·03	1·20	1·06
Smell after incubation	Earthy.	Sweet.	Sweet.
Chlorine	4·06	4·64	4·86
Gases ; Parts per 1,000 *by volume.*			
Carbon dioxide (free)	13·99	18·63	19·21
Oxygen (boiled out)	3·03	3·50	2·75
" (by cuprous chloride)			
(a) when drawn	——	——	——
(b) " analysed	——	——	——
Nitrogen	14·74	15·22	15·05
Remarks	Much dark brown flocculent matter present, the filtered liquid having only a faint brown tint. Clean, earthy smell. Slightly alkaline. Very considerable amount of lime and much sulphate. A fair amount of ferric oxide in suspension, and a trace in solution.	Slightly turbid and brownish, with a good deal of grey-brown flocculent matter in large aggregates. The filtered liquid had a very slight brown tint. Clean smell. *Very* slightly alkaline. A great deal of lime and sulphate in solution. More ferric iron in suspension than in solution.	Slightly brown, with considerable grey-brown flocculent matter in large aggregates ; had a slight brown tint when filtered. Clean iron earthy smell. Reaction inclining to alkaline. Very considerable amount of lime and much sulphate. A fair amount of ferric iron (mostly in suspension).

ALTRINCHAM SEWAGE FARM, 1900–1.

Brook Water alone and admixed with Effluent.

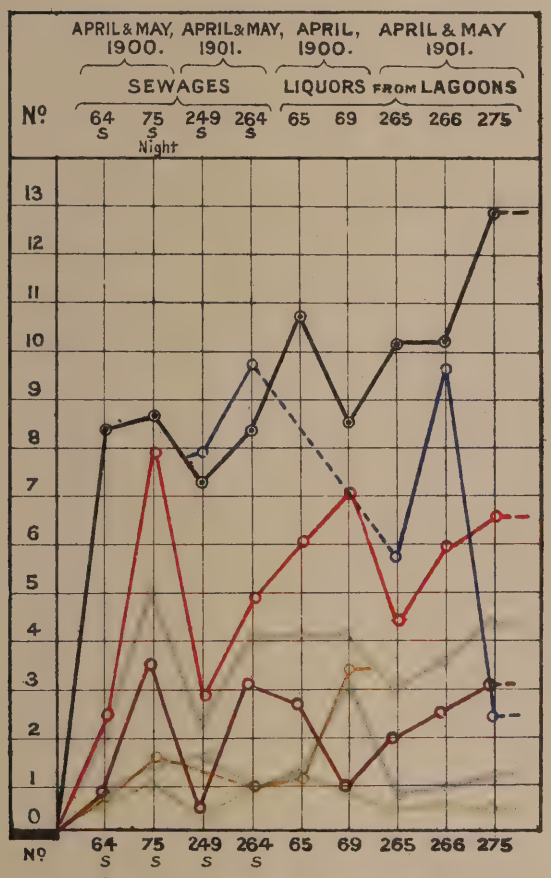
251a Brook Water above effluent outfall. Stream in flood and dirty brown.	251a Small Duplicate.	274a Brook Water above effluent outfall. Tan liquor coming down; brook black as ink.	276a Brook Water below effluent outfall. Small sample. Dirty colour.	78 Subsoil Water.
Thursday, 18th April 1901, 12·45 noon.	— —	Tuesday, 7th May 1901, 3 p.m.	Wednesday, 8th May 1901, 12 noon.	Wednesday, 16th May 1900, 12.20 noon.
8·3° C. (47° F.)	—	11·1° C. (52° F.)	10° C. (50° F.)	9·4° C. (49° F.)
12·2° C. (54° F.)	—	11·1° C. (52° F.)	13·3° C. (56° F.)	—
—	Jointed and incubated, 19th April.	Jointed and incubated, 9th May.	Jointed and incubated, 9th May.	—
19th April 1901.	25th April 1901.	Opened 23rd May.	31st May 1901.	24th May 1900.
Turbid.	—		—	Turbid.
0·038	—		0·51	0·18
0·042	—		0·05	0·10
None.	None.		None.	None.
0·37	0·43		None.	0·57
0·58	—		—	0·96
(0·16 in 1·00)	—		—	(0·19 in 1·58)
None.	—		—	None.
0·13	—		—	0·11
0·17	—		—	0·21
0·07	—		—	Too turbid to Nesslerize.
0·16	0·13		0·22	0·51
0·80	—		—	2·46
0·17	—		—	0·38
0·77	—		—	2·38
Sweet; Nitrite Nitrogen = 0·04 approximately.	—		Clean earthy.	Sweet.
2·80	—		—	1·54
—	—		—	17·67
—	—		—	0·06
—	—		2·0*	—
5·5	About 1·85 (estimation made after shaking up sediment).		None.	—
—	—		—	16·92
This sample was brown and opalescent, with a small amount of dark brown sediment; almost colourless when filtered. No smell. Alkaline.	—	The liquor and sediment were now black (so far as could be judged without filtering). Smell of sulphuretted hydrogen. Slightly alkaline in the cold; very alkaline on boiling. Not analysed.	After incubation this showed a moderate amount of dark brown sediment. Clean earthy smell. Alkaline. *Bad colour to read.	This sample was so muddy that it had to stand in the Winchester. First ⅜″ heavy sediment (mud with some grit) was deposited, and then ½″ grey-brown flocculent matter (hydroxide of iron and peaty matter). The liquid was still brown when analysed, the turbidity being caused by iron with some peaty matter. The reaction was distinctly acid, and more so after boiling, which gave rise to a flocculent precipitate. The boiled filtered liquid was clear, and very faintly brown. Odour very faint (iron?). Considerable amount of lime and much sulphate in solution; much ferric iron in suspension, and a little in solution. Little, if any, ferrous iron in suspension, but a moderate amount in solution. This sample boiled out very quickly and, to all intents and purposes, completely.

Diagram No. 10.

ALTRINCHAM SEWAGE FARM.

SEWAGES & LAGOON LIQUORS.

CURVES.



Note, S = Settled Sewage.

REFERENCE

Parts per 100.000, by Weight.

Albuminoid Nitrogen ..... *Shewn thus*

Organic Nitrogen by Kjeldahl, with Reduction .....

Organic Nitrogen by Kjeldahl, without Reduction .....

Ammoniacal Nitrogen .....

Total Nitrogen by Kjeldahl, with Reduction .....

"Oxygen absorbed" from Permanganate at 26·7°C (80°F.) in four hours .....

Chlorine (Combined) .....

Parts per 100.000. by Volume.

Solids in Suspension (by Centrifuge) (Scale divided by 10)

Note

Figures in the Vertical line represent "Parts per 100.000."

Figures in the Horizontal line represent the numbers of the Samples analysed.

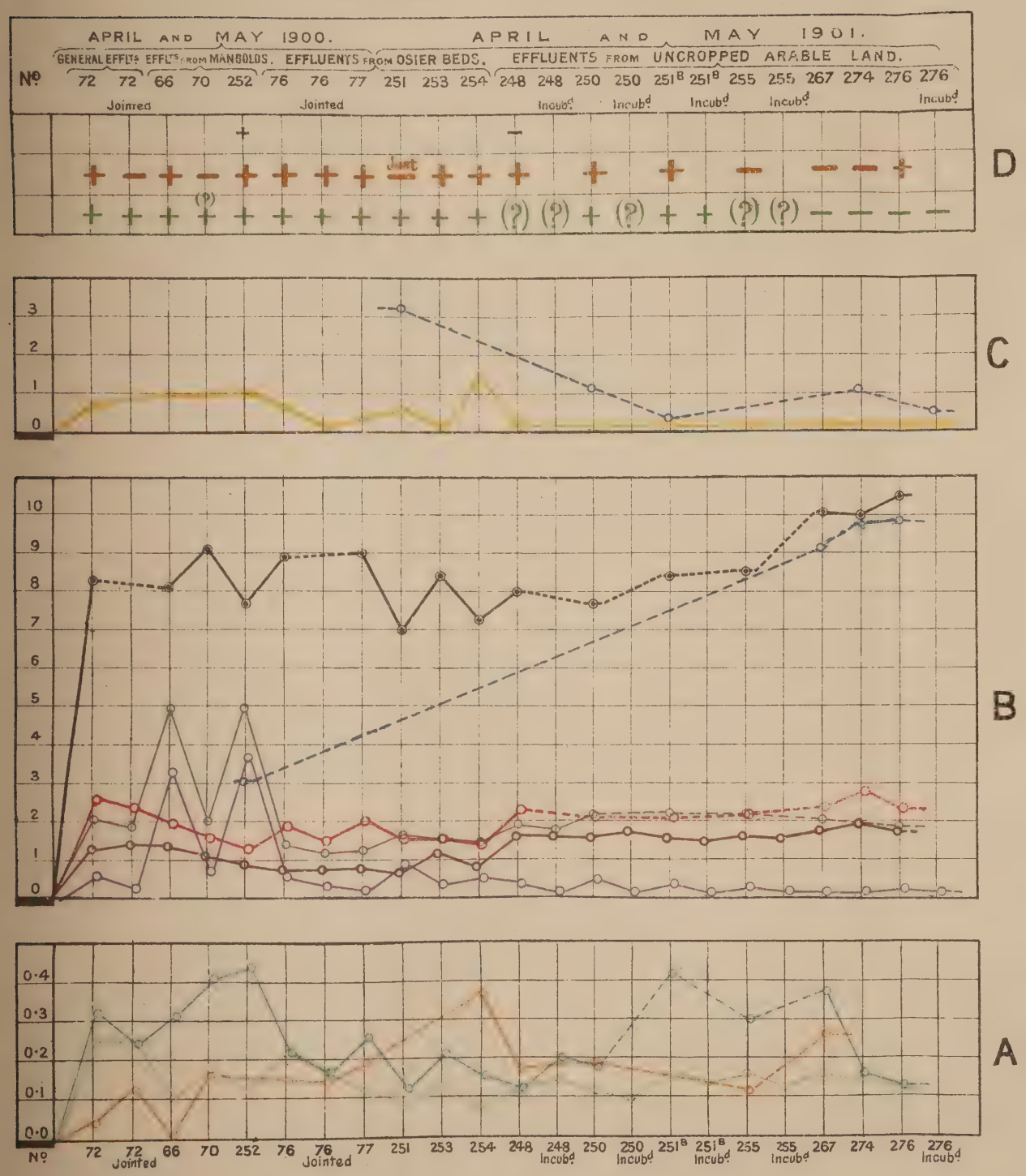
A dotted line is used when there is a break in the curve.

3332.8 02.

Weller & Graham Ltd Litho. London.

Diagram No. 11.

ALTRINCHAM SEWAGE FARM.
EFFLUENTS. — CURVES.



REFERENCE

Smell of Samples when drawn Shewn thus + or —

Scudder's Incubation Test + —

Incubation test as judged by Smell + —

Parts per 1,000, by Volume (C.C. per Litre)

Dissolved Oxygen when sample was drawn Shewn thus ———

Dissolved Oxygen when sample was analysed — —

Parts per 100,000. by Weight.

Ammoniacal Nitrogen ———

Total Nitrogen by Kjeldahl. with Reduction ———

Nitric + Nitrous Nitrogen (together) ———

"Oxygen absorbed" from Permanganate at 26·7°C (80°F.) in four hours ———

Chlorine (Combined) ———

Parts per 100,000. by Volume.

Solids in Suspension (by Centrifuge) (Scale divided by 10)

Parts per 100,000, by Weight.

Albuminoid Nitrogen Shewn thus ———

Organic Nitrogen by Kjeldahl, with Reduction ———

Organic Nitrogen by Kjeldahl, without Reduction ———

Note

"Jointed" Indicates a sample jointed and allowed to stand at laboratory temperature.

"Incubated" Indicates a sample jointed and allowed to stand for five days or longer at a temperature of 26.7°C (80°F.).

Note

Figures in the Vertical line represent "Parts per 100,000."

Figures in the Horizontal line represent the numbers of the Samples analysed.

A dotted line is used when there is a break in the curve.

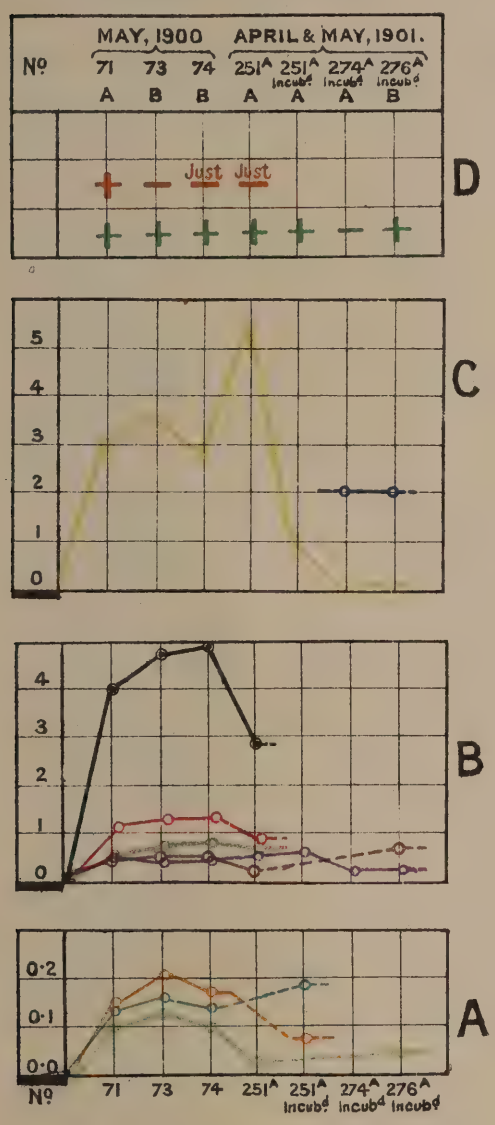
3332.8.02

Weller & Graham Ltd Litho. London.

Diagram No. 12.

ALTRINCHAM SEWAGE FARM.

BROOK WATER. CURVES.



Note
A *Means:-Drawn from above Effluent Outfall.*
B ..,,..,,..... *below*.....

REFERENCE

Scudder's Incubation Test..... + −

Incubation test as judged by Smell + −

Parts per 1.000, by Volume (C.C. per Litre)

Dissolved Oxygen when sample was drawn *Shewn thus* ———

Dissolved Oxygen when sample was analysed

Parts per 100.000, by Weight.

Ammoniacal Nitrogen..... ———

Total Nitrogen by Kjeldahl, with Reduction..... ———

Nitric + Nitrous Nitrogen (together)..... ———

"Oxygen absorbed" from Permanganate at 26·7°C (80°F.) in four hours..... ———

Chlorine (Combined)..... ———

Parts per 100.000, by Weight.

Albuminoid Nitrogen..... *Shewn thus* ———

Organic Nitrogen by Kjeldahl, with Reduction..... ———

Organic Nitrogen by Kjeldahl, without Reduction..... ———

Note

Figures in the Vertical line represent "Parts per 100.000."

Figures in the Horizontal line represent the numbers of the Samples analysed.

A dotted line is used when there is a break in the curve.

"Incubated" Indicates a sample jointed and allowed to stand for five days or longer at a temperature of 26.7°C (80°F.)

Weller & Graham. Ltd Litho. London.

CAMBRIDGE SEWAGE FARM.

Chemical Report.

1. Situation of Farm—On the Milton road, about three miles from Cambridge.
2. Total acreage of farm—102·5 acres.
3. Total irrigable area—74 acres.
4. Average area irrigated at one time—18·5 acres.
5. Population draining to farm—50,000.
6. Population per acre irrigated—675.
7. Gallons of sewage per head per day—45.
8. Dry weather flow of sewage per 24 hours—2,250,000 gallons.
9. Gallons of sewage treated per acre per 24 hours—121,600.
10. Gallons of sewage treated per acre per 24 hours, on the assumption that each acre of the irrigable area is under sewage all the time—30,400.
11. Character of the sewage—Mainly domestic (some brewery refuse).
12. Method of treatment—Screening, settling tanks, and land filtration.
13. General character of the soil and subsoil—Sandy loam overlying gravel and sand.
14. Separate or combined sewerage system—Partially separate.
15. The final effluent is discharged into—River Cam.
16. Number of years farm in operation (before 1900)—Five years (systematic working).

CAMBRIDGE SEWAGE FARM.

This farm is of comparatively recent date, having only been under sewage since the year 1895. It differs, however, in one respect from any other farm which the Commission has had under observation, in that for the first two and a half years of its life it treated the sewage admixed with a large quantity of lime ; at first fifteen grains of lime per gallon were added, but this quantity was gradually reduced to eight grains. As it was found, however, that this system of treatment was rapidly causing the farm to sludge up, it was discontinued in November, 1898, since which time no chemicals whatever have been employed. (*See* Part IV. Engineering and Practical Report.)

The irrigable area of the farm, when under observation, was 74 acres it is being extended), of which about one-fourth is sewaged at a time. A large portion of the farm is always uncropped, that is to say, the soil is mainly used as a bacterial filter, and so in this respect too the farm differs from the others which have been studied.

The farm is drained throughout at a depth of 3ft. 6in. to 6ft. ; and as the ground subsoil water in dry weather lies at a depth of 6ft. to 7ft., but little of this can get into the effluent. As at Nottingham and Aldershot Camp, the sewage can be treated only once. The effluents are therefore again *percolation effluents from one treatment of screened and settled sewage*, through an average depth of 4ft. 6in. of soil, upon which, as a rule, no crop is grown. The screenings are burnt, and the sludge is dug into the ground.

Soil and Subsoil.

To quote again from the Engineering Report :—" The surface soil on the farm is composed of 12in. to 15in. sandy loam, overlying a somewhat compact stratum of gravel and sand, the Gault clay lying at a depth of from 7ft. to 12ft from the ground level. About 2ft. to 2ft. 6in. from the surface soil a vein of sand impregnated with iron occurs in parts."

The following table gives the mechanical composition, etc., of average samples of the soil and subsoil :—

CAMBRIDGE SEWAGE FARM.

Name of Fraction.	Surface Soil per cent.			Subsoil per cent.		
	Not Ignited.	Ignited.	Difference.	Not Ignited.	Ignited.	Difference.
" Gravel " (above 8·0 m.m. diameter) -	—		—	20·87	20·87	—
Fine " Gravel " (above 2·0 m.m. diameter) -	4·84	4·70	0·14	19·40	18·87	0·53
Coarse " Sand " (above 1·0 m.m. diameter) -	1·59	1·46	0·13	4·18	4·06	0·12
Coarse " Sand " (above 0·5 m.m. diameter) -	1·80	1·68	0·12	4·26	4·13	0·13
Medium " Sand " (above 0·25 m.m. diameter)	4·03	3·92	0·11	7·82	7·70	0·12
" Sand " (0·25 to 0·05 m.m.) - - -	60·31	59·14	1·17	38·83	38·46	0·37
" Silt " (0·05 to 0·01 m.m.) - - -	17·63	15·85	1·78	2·14	1·96	0·18
" Dust " (from 0·01 m.m. downwards, which settles from water in 24 hours) - -	6·90	5·94	0·96	1·26	1·03	0·23
"Clay" (*i.e.*, the still finer residue precipitated from water by dilute nitric acid) - -	1·36	1·12	0·24	0·41	0·35	0·06
Loss on ignition (separate determination) -		5·00			1·20	
	98·46	98·81	4·65	99·17	98·63	1·74
Real specific gravity of soil dried at 110° C. -	2·603			2·631		
Apparent specific gravity - - - -	1·434			1·821		
Number of particles in 1 gramme of the ignited soil or sub-soil (approx.) - -	614,122,660			176,087,960		
Number of particles in 1 c.c. of the ignited soil or sub-soil (approx.) - - - -	880,665,516			320,657,693		
Weight of water retained by 100 grammes of the soil when fully drained - -	Grams. 29·0			Grams. 15·1		
Parts per 100,000.						
Lime dissolved by water in 24 hours - -	0·085			0·058		
Lime dissolved by water saturated with carbonic acid in 48 hours - - -	0·530			0·582		

For a discussion of the figures given in this table, the reader is referred to the Section upon Soils, page 275.

Volume treated per Acre, &c.

The sewage, which is dilute, may be taken as almost purely domestic, only a small quantity of refuse from two breweries being mixed with it. The normal dry weather flow is 2,225,000 gallons per 24 hours, and the population draining to the farm is 50,000. This therefore gives the large *volume* of 45 gallons of sewage per head, and the very high figure of 675 persons per acre of land irrigated. As the water supply is only 24 gallons per head, nearly half of the sewage must be derived from subsoil water gaining access to the sewers. The separate treatment of storm water (beyond twice the normal volume of sewage) is fully detailed in the Engineering Report.

As already stated, the average area under irrigation at one time is about 18·5 acres, one acre treating 121,600 gallons. But assuming, for purposes of comparison, the entire irrigable area to be under sewage continuously, *then each acre treats a volume of* 30,400 *gallons per* 24 *hours all the year round.* It will be noted that this is an exceptionally large volume, even allowing for the fact of the sewage being weak; and it contains *in the aggregate* an exceptionally large quantity of organic matter (*cf.* Diagram No. 4).

Nature of Sewage (*Diagram No.* 13).

This sewage is rather weak. From the centre of the town to the farm is a distance of about 3¼ miles, so that, with the screening at the pumping station and the breaking up action which the pumps exert, the sewage arrives at the farm in a well broken-up condition, generally speaking.

Although there is only about half an hour's settlement in the one tank at the farm, some 35 tons of sewage sludge are obtained each week. For the treatment of this sludge, *see* the Engineering Report. It will be noted from that Report that great care is taken to prevent sludge getting on the land unless it is actually wanted at any part of it. A considerable quantity of grease comes down at times from the college kitchens, which would no doubt have a very clogging effect upon the soil.

Eight samples of sewage were analysed, five chance ones and three sets of hourly samples drawn in equal quantities every hour of the day for 24 hours. The chance samples were taken in January, 1901, and the hourly samples in February, 1902. All of the chance samples, excepting one (No. 217), were much weaker than the hourly ones. No. 217 was drawn at 2.30 p.m., three of the other chance samples at 11.15 a.m., and the fourth at 12.20 a.m. The sewage is usually strongest between 11 a.m. and 2 p.m.

As regards the hourly samples, when No. 475 was being drawn, 0·2in. of rain fell, and when No. 477 was taken, 0·1in., and Mr. Kershaw wrote later about this:—"At Cambridge, the 0·2in. rainfall might add one-half to three-quarters to the normal flow of sewage." The effect of so much subsoil water getting into the sewers at Cambridge will tend to make sets of hourly samples of sewage, taken in equal quantities every hour, approximate in composition to sets of samples taken every hour in quantities proportionate to rate of flow. On the other hand, the rain which fell on two days of the three must have weakened the above hourly samples. The latter are, however, almost identical with one another. The average figures from the hourly samples, therefore, will be mainly relied upon for any approximate calculations that may be made, with this proviso, that these probably represent a somewhat weaker sewage than is actually treated on the farm, both because of the rainfall and because of the samples having been drawn in February.

Speaking generally, the above samples had but a faint sewage smell when they came to be analysed (Nos. 201 and 205B had no smell, and No. 215 a soapy smell); and most of them evidently contained (for a sewage) only moderate amounts of suspended matter, which was not in every case well broken up, small pieces of paper and tea-leaves being visible in two of the chance samples, and some of the solids being of appreciable size in the last set of hourly samples. In every case where the reaction was tested, it was alkaline. The temperature of the chance samples varied between 5·6 deg. and 10 deg. C. (42 deg. and 50 deg. F.). All of the eight samples were screened and settled, excepting No. 201 which was screened only.

The following figures give the more important analytical results :—

	Average.
Total Nitrogen—(*a*) 5 chance samples (1·50 to 11·52) - - -	3·94
(*b*) 3 sets of hourly samples (5·60 to 5·80) - - - -	5·71
Ammoniacal Nitrogen.—(*a*) 5 chance samples (0·69 to 7·31) -	2·41
(*b*) 3 sets of hourly samples (3·77 to 3·85) - - - -	3·82
Total Organic Nitrogen—(*a*) 5 chance samples (0·39 to 4·09) -	1·29
(*b*) 3 sets of hourly samples (1·73 to 1·95) - - -	1·88
Albuminoid Nitrogen—(*a*) 5 chance samples (0·28 to 1·52) - -	0·62
(*b*) 3 sets of hourly samples (0·89 to 0·96) - - - -	0·91
"*Oxygen absorbed*" *at* 26·7 *deg. C.* (80 *deg. F.*) *in* 4 *hours*—	
(*a*) 5 chance samples (2·07 to 17·81) - - - - -	6·99
(*b*) 3 sets of hourly samples (9·49 to 10·68) - - - -	10·08
Chlorine—(*a*) 5 chance samples (4·95 to 10·30) - - - -	6·37
(*b*) 3 sets of hourly samples (7·90 to 8·74) - - - -	8·45
Chlorine in Water Supply - - - - - - - - -	1·91
Chlorine in Subsoil Water (one analysis) - - - - - -	1·60
Ratio of Ammoniacal Nitrogen to Chlorine—3 sets of hourly samples - - - - - - - {1 : 2·05, 1 : 2·27, 1 : 2·31} -	1 : 2·21
Ratio of Ammoniacal Nitrogen to Chlorine, after deducting the Chlorine of the water supply—3 sets of hourly samples - - - - - {1 : 1·56, 1 : 1·77, 1 : 1·80} -	1 : 1·71
Solids in Suspension—3 sets of hourly samples (23·8 to 28·6) -	26·5
Solids in Suspension, by Centrifuge (*Volumes*)—3 sets of hourly samples (146 to 176) - - - - - - - - -	160
Ratio of Solids in Suspension to Centrifuge Solids - {1 : 5·50, 1 : 6·47, 1 : 6·13} -	1 : 6·03
Cellulose still containing fat—3 sets of hourly samples (one extraction with dilute alkali and one with dilute acid) (5·84 to 7·60)	6·87
Ratio of Celluloses containing fat to Suspended Solids—3 sets of hourly samples - - - - - {1 : 4·0, 1 : 3·6, 1 : 4·1} -	1 : 3·9
Cellulose—3 sets of hourly samples (extraction with alkali, acid and ether (3·84 to 5·08) - - - - - - - -	4·48
Ratio of Cellulose to Suspended Solids—3 sets of hourly samples - - - - - - - - - {1 : 5·6, 1 : 6·0, 1 : 6·2} -	1 : 5·9

The various curves of the figures obtained by the analysis of the Cambridge sewages are remarkable for the close way in which they follow one another, this applying especially to the three sets of hourly samples, which were very even in composition.

The hourly samples contained 5·7 parts total nitrogen, 1·88 parts organic nitrogen (of which 0·91 was albuminoid), and they gave the figure 10·08 for "oxygen absorbed"; further, they contained 26·5 parts of suspended solids. These figures alone are sufficient to show the comparative weakness of the sewage.

The *ratio of total organic to albuminoid nitrogen* increased with increasing strength of the sewage. In the hourly samples, as already mentioned, the total organic was as nearly as possible twice the albuminoid.

The average Ratio of Albuminoid Nitrogen to "Oxygen absorbed" in the five chance samples of sewage is 1 : 10·7, and in the three sets of hourly samples 1 : 11·0; in the chance samples this ratio is very uneven, but in the hourly ones very even.

The *ratio of the figures for organic nitrogen to those for "oxygen absorbed"* is 1 : 5·4, both in the chance and in the hourly samples. This is a rather higher ratio than was found in the other domestic sewages of Aldershot Camp, Beddington and South Norwood, and is very near to that of the Rugby sewage.

The hourly samples contained no nitrate when analysed, so there cannot have been much in the sewer subsoil water. Small quantities of nitrate and very appreciable quantities of nitrite were found in the chance samples examined for these, and it is obvious, from the general figures, that the proportion of subsoil water in the chance samples must have been great.

The *chlorine curve* bears rather a marked similarity in form to that for ammoniacal nitrogen.

The ratios in the hourly samples between the suspended solids, estimated gravimetrically, and the solids as determined volumetrically by the centrifuge, show a very fair agreement, the average being 1 : 6·03, and the ratios between the celluloses and the suspended solids were still more even, the average figures in this case being 1 : 5·9. Here again, therefore, for this particular (screened and settled) sewage, the rapid estimation of the solids volumetrically by the centrifuge gives a fair idea both of the proportion by weight of the solids in the sewage and also of the cellulose in those solids.

Effluents. (*Diagrams Nos.* 14 *and* 15).

As already mentioned, these are filtration effluents from one treatment of the screened and settled sewage through an average depth of 4ft. 6in. of soil and subsoil, the land being as a rule uncropped.

Eighteen original samples of effluent were examined, and eleven of these in duplicate after incubation, making a total of 29 analyses. They were all drawn between January 8th and February 6th, 1901. The seventeen effluents only varied in temperature between the narrow limits of 4·4 deg. and 6·7 deg. C. (40 deg. and 44 deg. F.); these temperatures were thus wonderfully even (compare the temperatures of the Nottingham farm effluents, and also Mr. Kershaw's tables and curves of average temperatures for a year).*

Of these, nine were general effluents (Nos. 204, 205, 207, 208, 209, 214, 214B, 220 and 221), and the others final effluents from separate plots of ground.

The following table shows some of the more important average analytical results from the examination of 17 to 18 effluents, full details being given in the annexed Tables of Analysis and Curves:—

	Average.
Total Nitrogen (1·48 to 3·19)	2·09
Ammoniacal Nitrogen (0·22 to 1·31)	0.65
Albuminoid Nitrogen (0.04 to 0·18)	0·09
Total Organic Nitrogen (0·04 (?) to 0·42)	0·21
Nitric and Nitrous Nitrogen (0·69 to 2·25)	1·26
"Oxygen absorbed" from permanganate at 26·7 deg. C. (80 deg. F.) *in 4 hours* (0·16 to 1·31)	0·81
Incubator Test (as judged by smell)	94 per cent. passed. (18 samples tested.)

The effluents were partly clear and colourless, and with no sediment, these being, as a rule, the effluents from special plots; partly slightly opalescent and of a

* Part IV. Engineering and Practical Report.

brownish tinge, with a little red, brown or grey flocculent matter, and in two cases with a considerable green deposit; partly rather turbid, this turbidity being no doubt mostly due to the separation of carbonate of lime from solution. The dimness was not, however, a criterion of purity or otherwise; Samples Nos. 204 and 205 were both dim, but the first was good and the second bad. All of them had a clean smell when they came to be analysed, though in two cases it was fishy, and in five others slightly fishy. The reaction was alkaline. Two effluents were tested for lime in solution, and, as was to be expected, a very large quantity of this was found to be present, together with a considerable amount of sulphate. One effluent (No. 203), out of two tested, showed a small amount of ferrous iron in solution.

The analytical tables and curves show very clearly the dilute character of the effluents, and also their comparative evenness in composition throughout; the chlorine curve is pretty nearly a straight line. The effluents would no doubt have been stronger in summer, but we had unfortunately no opportunity of examining any at that season of the year.

In only one case was there a little over 2 c.c. of dissolved oxygen per litre left in the effluents when they came to be analysed, the quantity sometimes going down to zero, and it never exceeded 4 c.c. when they were drawn, being as low in Sample No. 214 as 0·5 c.c. It must of course be borne in mind that these were percolation effluents. Speaking generally, when the dissolved oxygen in the sample was low at the time of drawing, the organic nitrogen was relatively high, and *vice versâ*. On the other hand, the diminution of dissolved oxygen between the times of drawing and of analysis was not great*. It would have been interesting if some duplicates of these samples had been fully aerated when drawn, and then tested for diminution of oxygen twenty-four hours later; but at the time this was not thought of.

I should like to refer at this point to Sample No. 210. When this was drawn, Mr Kershaw noted that there was an average thickness of ⅜in. of sludge all over the ground, after 10 days' intermittent sewaging. One might have expected that this would have interfered with the aeration of the soil and the consequent nitrification. But this effluent was a beautiful one, with practically no difference in the dissolved oxygen between the times of drawing and analysis; with practically all its nitrogen in the form of nitrate; and with very low figures indeed for albuminoid and organic introgen and for "oxygen absorbed." An effluent like this is certainly a strong argument in favour of intermittent sewaging at short intervals of time.

None of the samples were boiled out for dissolved carbonic acid and nitrogen.

The smell *when drawn* was no criterion of the keeping property of the effluents. Out of the fourteen of which the smell was noted upon drawing, seven had a slight smell, but of these only one for certain, with possibly a second, went wrong upon incubation.

The *Ammoniacal Nitrogen* in 18 of the above samples varied between 0·22 and 1·31, with an average of 0·65. It thus constituted about one-third of the total nitrogen.

The *Albuminoid Nitrogen* in 18 samples varied between 0·04 and 0·18, the average being 0·09. Nos. 209 and 214, which gave the highest figures for albuminoid nitrogen (viz., 0·18 and 0·13), both kept upon incubation.

The "*oxygen absorbed*" in 17 samples varied between 0·16 and 1·31, the average being 0·81.

The average ratio of Albuminoid Nitrogen to "Oxygen absorbed" from permanganate in 4 hours, after allowing for nitrite, was in sixteen effluents 1 : 8, the extremes being 1 : 4 and 1 : 11. Eight of the sixteen had a ratio varying between 1 : 8 and 1 : 10.

---

* NOTE.—It will be observed that there are a few discrepancies in the determinations of the dissolved oxygen (*a*), on drawing and (*b*) on analysis—in No. 203, for instance, it was greater when the sample came to be analysed. These discrepancies might arise from the fact that the readings of the blue copper tubes (two different sets) were made by two different people; or, some of the samples may have been difficult to read; or, possibly, the sample for analysis may have been more aerated than the other during the drawing.

On *incubation*, as has been already stated, only one sample (No. 205) out of eighteen became putrid, while in the case of 214B the smell of the incubated liquid was given as doubtful, which was certainly wrong, because of the quantity of nitrate left in the incubated duplicate. (Mr. Kershaw noted, with respect to the drawing of 214B, that it had a slight smell then, and that some of the plots required a rest). Mr. Scudder's incubator test passed No. 205, which was of course erroneous, and on the other hand it condemned Nos. 211, 212 and 216, all of which were undoubtedly good samples. This last test therefore is too stringent as regards the Cambridge effluents, and the smell after incubation is a safer guide than the decrease or increase in permanganate required.*

The *total nitrogen* in 17 effluents varied between 1·48 and 3·19, the average being 2·09, a low figure. On the whole, the quantity was fairly constant. Excepting in one case the highest amounts were in the general effluents.

The *total organic nitrogen*, as determined by Kjeldahl *with* reduction, varied in 17 samples between 0·04 (?) and 0·42, the average being 0·21. Here again, the largest quantities were found without exception in the general effluents. The total organic nitrogen is thus rather more than double the albuminoid (of which the average was 0·09), but the ratio is far from being a constant one (in some instances the quantity present was too small for accurate estimation by this method). As the effluents were usually either free from sediment or practically so, this organic nitrogen comes from matter in solution.

The determination of *organic nitrogen* by Kjeldahl *without* reduction was for the most part unreliable here, no doubt for the reasons given in the Report upon Methods of Chemical Analysis (Part V.).

Most of the Cambridge effluents contained small but relatively appreciable quantities of *nitrous nitrogen* when analysed—another index of uncompleted oxidation—the maximum amount being 0·13.

In such dilute effluents the *nitric nitrogen* could never of necessity be very large, though in the two samples, Nos. 210 and 210A, it constituted practically the whole of the nitrogen present; but excepting in two instances out of eleven tested (or, more probably, in two instances out of eighteen) there was always some reserve of nitrate left after incubation.

The *ratio of oxidised to unoxidised nitrogen* in seventeen samples (taking the unoxidised = 1) varied between 0·4 : 1 and 7·0 : 1, the average being 2·25 : 1. The safety limit of ratio in the case of those effluents apparently lies somewhere between 1 and 1·5 : 1, although two samples with ratios of 0·4 : 1 and 0·5 : 1 kept upon incubation. More results would be desirable here from samples just on the border line of safety.

The *ratio of oxidised to albuminoid nitrogen* in eighteen samples (taking the albuminoid = 1) varied between 5·1 and 39·3, the average being 17·6. The *safety limit* of ratio (for non-putrescence upon incubation) apparently lies between 7·6 and 14, say 10 : 1, although two samples with ratios of 8·8 : 1 and 5·1 : 1 kept on incubation. Here, again, more results are required before anything definite can be stated.

It is worth noting, however, that the ratio here is evidently a high one, which is what one would expect in dealing with effluents from such a dilute sewage. Or, to put the matter differently, if we take equal volumes of two sewages, A and B, the former, A, having twice the strength of B as regards total nitrogen, and if we purify them down to the same *absolute* amount of albuminoid nitrogen, the "safety limit" ratio required in the case of effluents from B will be greater than in effluents from A; for it is quite evident that the further the nitrogen is reduced in an effluent, the less putrescible (relatively) the residual nitrogenous matter becomes.

---

* The nitrite *after* incubation was not noted in the case of the Cambridge effluents. It has therefore been assumed as not being greater in the incubated than in the original sample. Thus, in tabulating the results of Mr. Scudder's test, the effluent has been given the benefit of the doubt, where doubt existed, this being more especially the case in samples 202, 209, 214, 214B, 220, and 221.

The *Chlorine* curve varied very little, a good proof of the "equalisation" of the liquid in the ground; on the whole, the general effluents gave rather the highest figures for chlorine.

The *Chlorine* in 18 effluents varied between 6·80 and 8·06, the average being - - - - - - - - - -	7·55
Deduct chlorine in water supply* - - - - - - - -	1·91
Chlorine derived from sewage - - - - - - - -	5·64

Chlorine in three 24-hourly samples of sewage (7·90 to 8·74) - -	8·45
Deduct chlorine in water supply - - - - - - - -	1·91
Chlorine from sewage alone - - - - - - - - -	6·54

These figures indicate about 14 per cent. dilution of the sewage on the farm by rain, assuming none to have been taken up by plants.

The resemblance between the "oxygen absorbed" curve and that for albuminoid nitrogen is very striking throughout in the case of these effluents, which, it may be repeated, are clear effluents from a weak sewage purified relatively to a medium extent.

The "oxygen absorbed" and "nitric nitrogen" curves vary almost inversely as one another.

No determinations were made of *suspended solids* either gravimetrically or volumetrically. The amounts present were of course very small, in some cases practically *nil.*

I have also included in this report a table marked "A," similar to the one made out for the Aldershot Camp effluents, together with a corresponding set of curves (*Diagram No.* 15), in order to show in a concise form some of the comparative results obtained from the analysis of duplicate samples of effluents before and after incubation.

* The chlorine in one sample of subsoil water was 1.60.

TABLE A.—CAMBRIDGE EFFLUENTS: EFFECT OF INCUBATION ON.

Parts per 100,000 by Weight.	No. 202.			No. 203.			No. 204.			No. 205.			No. 205C.		
	Original Sample.	Incubated Sample.	Increase or Decrease.	Original Sample.	Incubated Sample.	Increase or Decrease.	Original Sample.	Incubated Sample.	Increase or Decrease.	Original Sample.	Incubated Sample.	Increase or Decrease.	Original Sample.	Incubated Sample.	Increase or Decrease.
Nitric and Nitrous Nitrogen together -	2·25	2·48	+0·13	1·57	1·57	+0·0	1·07	0·91	−0·16	0·84	0·06	−0·78	1·06	1·03	−0·03
Ammoniacal ,, -	0·25	—	—	0·22	—	—	0·59	0·62	+0·03	0·76	—	—	0·30	—	—
Albuminoid ,, -	0·07	—	—	0·05	—	—	0·10	0·08	−0·02	0·11	—	—	0·04	—	—
Organic ,, -	0·07	—	—	0·20	—	—	0·25	—	—	0·21	—	—	0·16	—	—
Oxygen absorbed from Permanganate in 4 hours at 26·7° C. (80° F.) - -	0·48	—	—	0·28	—	—	0·75	—	—	1·31	—	—	0·38	—	—
Incubation by Scudder's Test - - -	+ ?	—	—	+	—	—	+	—	—	+	—	—	+	—	—
Incubation by Smell - - - - - -	+	+	—	+	+	—	+	+	—	−(?)	—	—	+	+	—
	No. 208.			No. 210A.			No. 212.			No. 214.			No. 214B.		
Nitric and Nitrous Nitrogen together -	1·15	0·21	−0·94	1·58	1·28	−0·30	0·69	0·41	−0·28	1·38	0·0	−1·38	1·72	0·87	−0·65
Ammoniacal ,, -	0·71	0·99	+0·28	0·25	—	—	0·63	0·69	+0·06	0·97	—	—	1·16	1·37	+0·21
Albuminoid ,, -	0·09	0·11	+0·02	0·05	—	—	0·09	0·06	−0·03	0·13	—	—	0·12	0·10	+0·02
Organic ,, -	0·21	—	—	0·05 (?)	—	—	0·16	—	—	0·32	—	—	0·31	—	—
Oxygen absorbed from Permanganate in 4 hours at 26·7° C. (80° F.) - -	1·10	—	—	?	—	—	0·80	—	—	1·10	—	—	1·16	—	—
Incubation by Scudder's Test - - -	+	—	—	+	—	—	—	—	—	+ ?	—	—	+ ?	—	—
Incubation by Smell - - - - - -	+	+	—	+ (no doubt)	—	—	+	+	—	+	—	—	(?)	+	—
	No. 221.			—			—			—			—		
Nitric and Nitrous Nitrogen together -	0·72	0·64	−0·08	—	—	—	—	—	—	—	—	—	—	—	—
Ammoniacal ,, -	1·31	1·35	+0·04	—	—	—	—	—	—	—	—	—	—	—	—
Albuminoid ,, -	0·14	0·10	−0·04	—	—	—	—	—	—	—	—	—	—	—	—
Organic ,, -	0·42	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Oxygen absorbed from Permanganate in 4 hours at 26·7° C. (80° F.) - -	1·28	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Incubation by Scudder's Test - - -	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Incubation by Smell - - - - - -	+	+	—	—	—	—	—	—	—	—	—	—	—	—	—

Leaving the dissolved oxygen, which was generally small, out of account in the meantime, there was usually a *relatively* large reserve of nitrate left in the effluents after incubation, but in four cases (Nos. 205, 208, 214 and 214B) out of eleven tested the nitrate had gone down by about 1 part, and was reduced to zero or nearly to zero in three out of the four. Now, in those four instances the "oxygen absorbed" figure in the original sample is rather high for Cambridge effluents, *viz.*, 1·1 to 1·38 parts per 100,000. The four hours "oxygen absorbed" test therefore furnishes a good criterion of the purity of these effluents, better, in fact, than either the albuminoid or total organic nitrogen, though on the whole it may be said that when the quantities of albuminoid and total organic nitrogen in the original sample are rather high, that sample will use up relatively much nitrate upon incubation. (It must of course be borne in mind here that in no one of the eighteen analyses did the organic nitrogen exceed 0·42 parts per 100,000, and in only four cases out of eighteen did it exceed 0·3 parts.) No. 221 is an apparent exception to what has just been said. Mr. Kershaw described it, when drawn, as "the worst effluent on the farm at the time. The snow has stirred up silt from the surface of the plots at the bottom of the farm and down air vents, thus fouling the effluent." But though this sample showed high figures not only for "oxygen absorbed" but also for albuminoid and total organic nitrogen, the nitrate did not perceptibly decrease on incubation nor the ammonia increase, showing that the organic matter present was of a comparatively stable character.

Out of five samples tested for increase of ammonia on incubation, in only Nos. 208 and 214B did any appreciable increase occur; and attention has already been drawn to the fact that in both of these there was a relatively large diminution of nitrate.

Further, with increase of ammoniacal nitrogen there is usually a slight decrease of albuminoid* nitrogen on incubation (*see* curves) and no doubt also a slight decrease of x nitrogen.

The duplicate samples of Nos. 202, 203 and 210A still retained after incubation small but appreciable amounts of dissolved oxygen (while there was of course practically no diminution of nitrate). This speaks well for the high degree of purity that can be attained by the Cambridge effluents, for the test is a most severe one. No. 203 is specially interesting, because the plot treating the sewage was covered with a thin layer of ice (*cf.* Mr. Kershaw's Notes on Samples†), and the temperature of the effluent was only 5·6 deg. C. (42 deg. F.). The sewage was diluted that day by a heavy fall of snow. Again, when 210A was drawn, the plot was treating a much stronger sewage than usual.

Four other samples may just be referred to before closing, *viz.*:

No. 210, another interesting sample, from the circumstances in which it was taken; this has already been referred to on p. 71.

No. 209, a general effluent, drawn when some of the plots were becoming rather thickly coated with sludge on the surface. As regards non-putrescibility this sample was good, though chemically not up to the standard of some of the others.

Nos. 211 and 212 were drawn on the same day from the same plot, the first when the effluent was running freely from the drains, and the second after the sewage had been kept in contact with the land for two hours and a half (the sewage treated was, however, stronger in the latter case). Of these two, No. 211 was distinctly the better.

Conclusion:—It will be seen that the Cambridge Sewage Farm treats, on a good porous soil and subsoil, an *exceptionally large* volume of a rather dilute sewage per acre, and at the same time an exceptionally large absolute amount of organic matter (compare Diagram No. 4), and produces from it a (dilute) effluent which is usually good, and in some instances, exceedingly good. At the same time, it is clear that the organic matter left in some of the less purified effluents is of a somewhat putrescible character, as judged by the incubator test, though there is nearly always enough nitrate present to keep the liquid sweet upon incubation. The approximate

* *Note.*—The difference in albuminoid nitrogen before and after incubation cannot be taken as being of very great consequence; what is wanted really is the difference in the figures for total organic nitrogen.

† Part IV.: Engineering and Practical Report.

number of particles per gramme of ignited soil is 614,122,660, and per gramme of subsoil 176,087,960. Or, the approximate numbers of particles in unit weights of ignited soil and subsoil, taking the numbers at Nottingham as 100 in each case, are :—soil 75 ; subsoil 61. The relative calculated *internal* filtering area at Cambridge per unit of surface, down to the drains, works out to about three-quarters of that at Nottingham. The rate of filtration at Cambridge must be a medium rate, probably rather faster than that at Nottingham. (Compare Section dealing with Soils, and also *Conclusions*).

Percentage purification, as calculated on the albuminoid nitrogen and "oxygen absorbed" in four hours.

(1) *Albuminoid Nitrogen.*

		Average.
5 chance samples of screened and settled sewage gave - - - - - - -	(0·28 to 1·52) -	0·62
3 sets of 24 hourly samples of screened and settled sewage gave - - - - - -	(0·89 to 0·96) -	0·91
18 samples of final and general effluents gave	(0·04 to 0·18) -	0·094

The percentage purification, therefore, was—

on the chance samples -	84·8 per cent.
on the hourly - - -	89·7 per cent.

(2) *"Oxygen absorbed."*

5 chance samples of screened and settled sewage gave - - - - - - -	(2·07 to 17·81) -	6·99
3 sets of 24 hourly samples of sewage gave	(9·49 to 10·68) -	10·08
17 samples of final and general effluents gave	(0·16 to 1·31) -	0·81

The percentage purification, therefore, was—

on the chance samples -	88·4 per cent.
on the hourly - - -	92·0 per cent.

Comparison of the total nitrogen in the sewage and final effluents.

	Average.
The average *total nitrogen* in the three sets of 24 hourly samples of sewage was (5·60 to 5·80) - - - - - - - -	5·71
The average *total nitrogen* in 17 effluents (1·48 to 3·19) -	2·09

If we take the chlorine figures as an index of the dilution by rain, the second figure 2·09 becomes $2{\cdot}09 \times \frac{100}{86} = 2{\cdot}43$. Disregarding any subsoil water on the one hand, and loss by evaporation on the other (there would probably not be much evaporation in January and February), the above figures show that some 40 per cent. of the nitrogen of the original sewage runs into the river.

Subsoil Water.

One sample of subsoil water (No. 219) was examined, in duplicate, *i.e.*, one bottle of it was analysed the day after drawing, while the other was mercury-jointed and examined after being kept at laboratory temperature for two months (January 31st to March 28th, 1901). The water was drawn from a field in the neighbourhood of the farm, which was not in such a position as to be affected by the farm itself.

As will be seen from a glance at the figures of analysis, this water was very pure, containing practically no oxidisable organic matter, for the dissolved oxygen in it suffered hardly any diminution during those two months. There was a considerable amount of nitrate in it, however. The chlorine (1·6) was practically the same as that in the town's water supply (1·91).

Apart from sandy sediment, without which the sample could not be drawn, the water itself was clear and colourless and without smell. It contained much lime in solution and also a considerable amount of sulphate, but no appreciable iron.

Water from the river Cam, with and without admixed effluent. (*Diagram No.* 16.)

In the Engineering Report Mr. Kershaw says: –"There is one main effluent outfall, discharging into the River Cam a short distance below Baitsbite lock. The river at this point has a normal flow of about 30 million gallons per 24 hours, and a very slow current; it appeared to be in good condition. The volume of effluent as compared to the volume of the river is about 1 : 15 normally. A small quantity of sewage fungus was noticeable at times issuing from the main effluent outfall, which has a submerged outlet."

Only five samples were examined, two of them in duplicate after incubation, making seven complete or partial analyses in all. Of these, Nos. 206, 209 and 222 were taken above the effluent outfall and Nos 214A and 223 below it. The various samples were either clear and colourless or slightly turbid, some of them with small but appreciable amounts of sediment; they had either no smell or a slight earthy one. No. 206 contained a great deal of lime in solution, only a rather small amount of sulphate, and no iron; the other samples were not tested for these.

Too few analyses were made to allow of drawing many conclusions, but those that were done show the river to have been in a fair state for *a non-drinking water stream* in January and February, 1901. Incubation did not by any means exhaust the dissolved oxygen in three out of four samples noted; in the fourth (No. 214A). which was drawn 100 yards below the effluent outfall, the dissolved oxygen was practically exhausted after incubation, but plenty of nitrate remained. This being the case, there was of course no question of putrescibility. Curiously enough, Mr. Scudder's incubation permanganate test was adverse to these samples, so it was obviously too stringent. The nitrate was practically a constant quantity, the curve being nearly a straight line.

Nos 222 and 223 are comparable samples, having been drawn on the same day (*a*) above and (*b*) 10 yards below the effluent outfall. There is no very great difference between them, excepting as regards ammoniacal nitrogen and chlorine.

Buried sludge from Cambridge Sewage Farm (*See* Tables of Analysis, p. 87).

CAMBRIDGE SEWAGE FARM.

TABLES OF ANALYSIS.

INDEX.

	PAGE.
Hourly Sewage Samples, Nos. 475, 476, 477	79
Sewages and Effluents, Nos. 201, 202, 203, 204, 205, 205A, 205C	80—81
Effluents, Nos. 207, 208, 209, 210, 210A, 211, 212	82—83
Sewages and Effluents, Nos. 213, 214, 214B, 215, 216, 217, 218	84—85
Effluents, Nos. 220, 221	86
Buried Sludge	87
River Water above and below Effluent outfall:—	
Nos. 206, 209A, 214A	88
Nos. 222, 223	89
Subsoil Water, No. 219	89

CAMBRIDGE SEWAGE FARM, 1902.

Sets of Hourly Sewage Samples drawn in equal quantities per hour.

No. of Sample	475	476 (2).	477 (2).
Nature of Sample	Screened and Settled Sewage. 24 hours' sample.	Screened and Settled Sewage. 24 hours' sample.	Screened and Settled Sewage. 24 hours' sample.
Rainfall while sample was being drawn.	0·20″ (1)	0·00″	0·10″
Drawn	From Monday 24th February 1902, 12 noon, to 25th February, 11 a.m.	From Tuesday 25th February, 12 noon, to 26th February, 11 a.m.	From Wednesday 26th February, 12 noon, to 27th February, 11 a.m.
Analysed	26th February 1902.	28th February 1902.	1st March 1902.
Parts per 100,000, *by weight.*			
Ammoniacal nitrogen (by distillation)	3·85	3·85	3·77
Albuminoid nitrogen	0·89	0·96	0·89
Nitrous ,,	None	None.	None.
Nitric ,,	0·02	None.	None.
Total nitrogen by Kjeldahl, *with* reduction.	5·60	5·80	5·72
Blank	(0·45 in 4·54)	(0·45 in 4·69)	(0·45 in 4·63)
"X" nitrogen	0·84	0·99	1·06
Organic nitrogen by Kjeldahl, *with* reduction.	1·73	1·95	1·95
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once.*	2·15	2·19	2·08
,, ,, ,, *after four hours*	10·07	10·68	9·49
Chlorine	7·90	8·74	8·70
Total solids (gravimetrically)	101·8 { 40·2 Volatile, 61·6 Non-vol.	108·6 { 40·8 volatile, 67·8 Non-vol.	101·2 { 41·8 Volatile, 59·4 Non-vol.
Solids in suspension ,,	28·6 { 20·8 Volatile, 7·8 Non-vol.	27·2 { 16·8 Volatile, 10·4 Non-vol.	23·8 { 16·0 Volatile, 7·8 Non-vol.
Solids in solution ,,	73·2 { 19·4 Volatile, 53·8 Non-vol.	81·4 { 24·0 Volatile, 57·4 Non-vol.	77·4 { 25·8 Volatile, 51·6 Non-vol.
Cellulose still containing fat (by extraction with alkali and acid alone) (a).	7·16	7·69	5·84
Cellulose (by alkali, acid and ether) (b)	5·08	4·52	3·84
Grit { from (a)	4·52	2·28	2·40
Grit { from (b)	4·88	2·28	2·36
Parts per 100,000, *by volume.*			
Solids by Centrifuge	157·0 (3 minutes)	176·0 (3 minutes)	146·0 (3 minutes)
Remarks	Turbid and brown, with a rather small amount of brown suspended matter. Faint sewage smell. General solids up to 0·73 mm. long. Fibre (not much) - 0·52 Hair (very little) - 3·02 *Note.*—(1) Mr. Kershaw wrote on May 14th, 1902, about this:—"At Cambridge the 0·2″ of rainfall might add from one-half to three-quarters to the normal flow."	Turbid and brown, with apparently less deposit than No. 475. Very faint sewage smell. Alkaline. Solids up to 0·36 mm. Fibre - 0·88 mm. Hair - 0·52 ,,	Turbid and brown with apparently about the same amount of deposit as No. 476. Distinct sewage smell. Alkaline. Solids up to 5·20 mm. Fibre - 4·70 mm. Hair - 26·8 ,,

(2) These samples were delayed in transit.

CAMBRIDGE SEWAGE FARM, 1901.

Sewage and Effluents.

No. of Sample	201	202	202	203	203
Nature of Sample	Roughly Screened Sewage (a weak sample, apparently containing a large quantity of subsoil water).	Final Effluent corresponding to Sewage No. 201.	Small Duplicate.	Effluent from same source as No. 202, after 28 hours sewaging with dilute sewage. Plot covered with ice.	Small Duplicate.
Drawn	Tuesday, 8th January 1901, 12.20 noon.	Tuesday, 8th January 1901, 1.30 p.m.	—	Wednesday, 9th January 1901, 11.25 a.m.	—
Temperature of sample	6·7° C. (44° F.)	6·1° C. (43° F.)	—	5·6° C. (42° F.)	—
Temperature of air	0·6° C. (33° F.)	2·2° C. (36° F.)	—	0·0° C. (32° F.)	—
If jointed or incubated	—	—	Jointed and incubated 9th January.	—	Jointed and incubated, 10th January.
Analysed	9th January 1901.	9th January 1901.	14th January 1901.	10th January 1901.	15th January 1901.
Parts per 100,000, *by weight.*					
Ammoniacal nitrogen:					
(a) by direct Nesslerization	—	—	—	—	—
(b) by distillation	2·12	0·25	—	0·22	—
Albuminoid nitrogen	0·53	0·07	—	0·05	—
Nitrous ,,	0·19	0·02	None.	Trace.	None.
Nitric ,,	Not done. There might have been nitrate here.	2·23	2·48	1·57	1·57
Total nitrogen by Kjeldahl, *with* reduction (after nitrite correction)	2·95	2·56	—	1·99	—
Blank	(0·14 in 4·28)	(0·34 in 4·08)	—	(0·34 in 3·11)	—
Correction for nitrite	+ ·10	+0·01	—	None.	—
"X" nitrogen	0·11	None (— 0·01)	—	0·15	—
Organic nitrogen by Kjeldahl, *with* reduction	0·64	0·07	—	0·20	—
Organic nitrogen by Kjeldahl, *without* reduction: Taking ammonia by distillation	—	None (— 0·04)	—	0·02	—
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once*	1·95	0·28	—	0·18	—
,, ,, ,, *after four hours.*	7·14	0·48	—	0·28	—
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once*	—	0·27	—	0·12	—
,, ,, ,, *after four hours.*	—	0·38	—	0·40	—
Smell after incubation	—	Not so sweet smelling as original sample, but not putrid.	Earthy.	Sweet.	—
Chlorine	5·68	7·48	—	7·50	—
Gases: Parts per 1,000, *by volume.*					
Oxygen (by cuprous chloride):					
(a) When sample was drawn	—	3·75	—	*0·75	—
(b) ,, ,, ,, analysed	—	2·3, 1·75, 1·75 — On 9th Jan. Three observers.	0·8	1·75, 1·8, 1·6 — Three observers.	0·5
Remarks	Very dilute sample. Slight brown and grey deposit, with some tea-leaf. No smell. Alkaline.	Very faintly opalescent, and with but a minute quantity of brown-red flocculent matter. Clean earthy smell. A *very* large quantity of lime in solution, with a fair amount of sulphate. No iron in solution, or practically none.	After incubation this had an earthy smell.	Clear and colourless, with no sediment. Hardly any smell (quite clean). *This must surely have been wrong.	The only change here is that the oxygen has decreased by 1 c.c. on incubation.

CAMBRIDGE SEWAGE FARM, 1901.

Sewage and Effluents.

204 General Effluent (combined.)	204 Small Duplicate.	205 General Effluent.	205 Small Duplicate.	205B Settled Sewage through Tanks (very dilute; much grease coming down).	205C Special Effluent corresponding to No. 205B, off No. 4 field, sewaged one day. Ice gone.	205C Small Duplicate.
ednesday, 9th anuary 1901, 2.15 noon.	—	Thursday 10th January 1901, 11.45 a.m.	—	Saturday 12th January 1901, 11.15 a.m.	Saturday 12th January 1901, 12.20 noon.	—
5·6° C. (42° F.)	—	5·0° C. (41° F.)	—	10° C. (50° F.)	5·6° C. (42° F.)	—
0° C. (32° F.)	—	5·6° C. (42° F.)	—	5·0 C. (41° F.)	5·0° C. (41° F.)	—
—	Jointed and incubated 10th January.	—	Jointed and incubated 11th January.	—	—	Jointed and incubated 14th January.
h January 1901.	18th January 1901.	11th January 1901.	21st January 1901.	14th January 1901.	14th January 1901.	4th February 1901.
Turbid.	—	Turbid.	—	—	Turbid.	—
0·59	0·62	0·76	—	1·02	0·30	—
0·10	0·08	0·11	—	0·28	0·04	—
0·01	None.	0·08	None.	0·09	None.	} 1·03
1·06	0·91	0·76	0·06	Not done. Should have been.	1·06	—
hout ugar. ·90 With sugar. 1·91	—	Without sugar. 1·80 With sugar. 1·82	—	1·50	Without sugar. 1·52 With sugar. 1·51	—
1 in 85) (0·14 in 2·90)	—	(0·11 in 2·66) (0·14 in 2·73)	—	(0·34 in 2·46)	(0·11 in 2·32) (0·14 in 2·33)	—
+ ·01	—	+ ·04 + ·04	—	+ ·05	None.	—
0·15	—	0·10	—	0·11	0·12	—
0·25	—	0·21	—	0·39	0·16	—
—	—	0·31	—	—	0·04	—
0·17	—	0·31	0·15	0·66	0·14	—
0·75	—	1·31	—	2·07	0·38	—
0·16	—	0·19	—	—	0·08 } 7 days.	—
0·78	—	0·82	—	—	0·36 } 7 days.	—
Earthy.	—	Just putrid or doubtful (three observers).	Distinctly putrid and also smell of sulphuretted hydrogen.	—	Sweet.	—
7·66	—	7·54	—	(a) 5·00 (b) 4·90	6·80	—
1·25	—	1·5	—	—	1·0	—
little over { 1·0 1·0 0·75 } Three observers. ery dim to read.	—	Trace, *i.e.* much less than 1 c.c. (two observers). Very dim to read.	—	—	1·2 0·9 0·85 } Four observers.	Trace only.
is effluent was im, the dimness eing partly due lime, I think, ith a little—but ppreciable—light rown flocculent atter. Clean nell (somewhat shy-earthy). *ry* large amount f lime in solution. onsiderable amunt of sulphate. mall amount of ron (evidently errous).	Slight brownish sediment. Earthy smell, *i.e.*, sweet.	This sample was dim and turbid, but with only a very little brown flocculent matter. Clean, slightly fishy-earthy smell. *Note.*—It is instructive that this sample should have gone putrid.	After incubation this was slightly brown and clear. No sediment.	Slightly turbid, the filtered liquid being practically colourless. Considerable amount of grey sediment, consisting largely of small pieces of paper. Practically no smell. Alkaline.	This sample was clear with a slight brownish tinge and no sediment. No smell. Alkaline.	Beyond losing its small amount of oxygen, this incubated sample has undergone practically no change.

CAMBRIDGE SEWAGE FARM, 1901.

Effluents.

No. of Sample	207	208	208	209
Nature of Sample	General Effluent (slight iron smell).	General Effluent (slight iron smell on shaking).	Small Duplicate.	General Effluent.
Drawn	Monday, 14th January 1901, 11.30 a.m.	Tuesday, 15th January 1901, 11.15 a.m.	—	Wednesday, 16th January 1901, 11.40 a.m.
Temperature of sample	5·0° C. (41° F.)	5·0° C. (41° F.)	—	4·4° C. (40° F.)
Temperature of air	5·6° C. (42° F.)	1·7° C. (35° F.)	—	4·4° C. (40° F.)
If jointed or incubated	—	—	Jointed and incubated 16th January.	—
Analysed	15th January 1901.	16th January 1901.	6th February 1901.	17th January 1901.
Parts per 100,000, *by weight.*				
Ammoniacal nitrogen: (a) by direct Nesslerization	Turbid.	—	—	Turbid.
(b) by distillation	0·85	0·71	0·99	0·74
Albuminoid nitrogen	0·10	0·09	0·11	0·18
Nitrous ,,	0·07	0·07	0·02 approx.	0·05
Nitric ,,	1·63	1·08	0·19 *Note.*—The reduction in nitrate here is very striking.	0·91* to 0·96
Total nitrogen by Kjeldahl, *with* reduction (after correction for nitrite.)	Without. 2·78 / With sugar. 2·82	2·07	—	Without. 1·90 / With sugar 1·90
Blank	(·11 in 4·09)	(·14 in 4·17)	(0·34 in 3·31)	—	(0·11 in 2·83)	(0·14 in 2·86
Correction for nitrite	+ ·04	+ ·04	+ ·04	—	+ ·03
"X" nitrogen	0·13	0·17	0·12	—	0·02 (?)
Organic nitrogen	0·23	0·27	0·21	—	0·22 (?)
Organic nitrogen by Kjeldahl, *without* reduction: Taking ammonia by distillation	0·13	Lost.	—	0·26
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once.*	0·42	0·28	0·29	0·28
,, ,, ,, *after four hours.*	1·12	1·10	—	1·31
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once.*	0·27 (six days.)	0·09 (twelve days.)	—	0·28
,, ,, ,, *after four hours.*	0·99 (six days.)	0·49 (twelve days.)	—	0·85
Smell after incubation	Sweet.	Sweet.	—	Sweet.
Chlorine	7·40	7·82	—	7·74
Gases; Parts per 1,000, *by volume.*				
Oxygen (by cuprous chloride): (a) When drawn	2·5	2·75	—	2·0
(b) When analysed	0·75, 0·75 (two observers.)	Not entered on 16th.	—	None.
Remarks	When drawn, there was some flocculent red matter in this liquid. On 15th January it was slightly opalescent with a rather considerable green deposit, with black specks in it (also a good sized worm). Earthy smell.	Mr. Kershaw says "This is apparently a fair average sample of the general effluent for the time of year." On 16th January the sample was rather turbid (from lime, no doubt), the liquid itself being practically colourless. Very little sediment but a moderate amount of (yellow) weed.	After incubation the liquid was clear and slightly brown, with a considerable amount of aggregated brown flocculent matter. No smell.	Opalescent. A considerable quantity of greenish matter (weed evidently). Clean smell. Alkaline. When this sample was drawn, some of the plots were becoming rather thickly coated with sewage sludge. *A few drops lost at the end of nitrate distillation.

CAMBRIDGE SEWAGE FARM, 1901.

Effluents.

210	210a	210a	211	212	212
FINAL EFFLUENT from No. 4 Plot, which had been sewaged 12 hours a day for 10 days.	EFFLUENT from Field No. 4 (clear, no smell).	SMALL DUPLICATE.	EFFLUENT drawn when running freely away from the drains.	SAME EFFLUENT as No. 211, but after being kept in contact with land for 2½ hours. Sewage was however stronger from 1 to 2 p.m. than from 11 to 12.30 a.m.	SMALL DUPLICATE.
Wednesday, 16th January 1901, 12.30 noon.	Friday, 18th January 1901, 2.40 p.m.	—	Monday, 21st January 1901, 1.45 p.m.	Monday, 21st January 1901, 4.45 p.m.	—
5·6° C. (42° F.)	6·1° C. (43° F.)	—	6·7° C. (44° F.)	5·6° C. (42° F.)	—
5.0° C. (41° F.)	7·2° C. (45° F.)	—	11·1° C. (52° F.)	10·6° C. (51° F.)	—
—	—	Jointed and incubated 19th January.	—	—	Jointed and incubated 22nd January.
17th January 1901.	19th January 1901.	11th February 1901.	22nd January 1901.	23rd January 1901.	8th February 1901.
—	—	—	Turbid.	Turbid.	—
0·22	0·25	—	0·42	0·63	0·69
0·04	0·05	—	0·08	0·09	0·06
Trace.	Trace.	None.	0·02	0·04	0·03
1·57	1·58	1·28	1·14	0·65	0·41
			Sugar. Naked flame. / Sugar. Sandbath.	Sugar. Gauze flame. / Sugar. Sandbath.	
1·70	1·62	—	1·67 / 1·64	1·50 / 1·46	—
(0·34 in 2·83)	(0·34 in 2·71)	—	(·14 in 2·55) (·14 in 2·57)	(·14 in 2·29) (·14 in 2·25)	—
None.	None.	—	+ ·01 + ·01	+ ·02 + ·02	—
None (–0·13 !)	None (–0·26 !)	—	0·01 None (–0·02)	0·09 0·05	—
(?)	—	—	0·09 0·08	0·18 0·14	—
Lost.	None (–0·08)	—	0·04 { very turbid.	0·35	—
0·04	0·03	—	0·16	0·18	0·12
0·16	—	—	0·59	0·80	—
0·01	None } eight days.	—	0·23 } six days.	0·24	—
0·32	0·27 } eight days.	—	0·42 } six days.	0·61	—
Sweet.	—	—	Sweet.	Sweet.	Earthy.
7·28	7·66	—	7·14	7·56	—
2·75	3·0	—	4·0	1·25	—
2·3 to 2·5 { three observers.	1·3 } two observers. 1·2 } two observers.	0·5 { three observers.	1·6 } two observers. 1·7 } two observers.	None, or merest trace.	—
This was a beautifully clear and almost colourless effluent with no visible sediment. No smell. Alkaline. When this sample was drawn, there was on an average ⅜″ of sludge over the ground. One would have expected this to interfere with the nitrification (*i.e.* the aeration).	Clear and almost colourless. No sediment. No smell. Alkaline. The sewage going on to this plot was much stronger than usual, and of a dark brown colour.	Quite colourless and clear after incubation. No sediment. No smell.	This sample was slightly opalescent and nearly colourless, but with a slight brownish tinge. A trace of brownish sediment. Slight fishy-earthy smell. Alkaline.	This sample was dim, with a small amount of grey sediment. Clean earthy smell. As might have been expected, this is not such a good sample as No. 211.	After incubation, slight brown sediment in a clear liquid. Earthy smell. Very good sample.

CAMBRIDGE SEWAGE FARM, 1901.

Sewages and Effluents.

No. of Sample	No. 213	214	214	214 B
Nature of Sample	Screened and Settled Sewage (very dilute).	General Effluent, corresponding to Sewage No. 213, (very slight smell).	Small Duplicate.	General Effluent (slightly cloudy; slight smell, some plots requiring a rest).
Drawn	Wednesday 23rd January 1901. 11.15 a.m.	——	——	Saturday 26th Jannuary 1901, 12·45 noon.
Temperature of sample	10·0° C. (50° F.)	5·6° C. (42° F.)	——	5·6° C. (42° F.)
Temperature of air	5·6° C. (42° F.)	6·1° C. (43 F.)	——	5·6° C. (42° F.)
If jointed or incubated	——	——	Jointed and incubated 24th Jan. Opened 11th Feb. 1901.	——
Analysed	24th January 1901.	25th January 1901.		28th January 1901.
Parts per 100,000, *by weight.*				
Ammoniacal nitrogen:				
(a) by direct Nesslerization	——	Turbid.	——	Turbid.
(b) by distillation	0·69	0·97	——	1·16
Albuminoid nitrogen	0·35	0·13	——	0·12
Nitrous "	0·22	0·06	——	0·09
Nitric "	0·10	1·32	——	1·63
Total nitrogen by Kjeldahl, *with* reduction (after correction for nitrite).	Sugar. Naked flame. 1·40; Sugar. Sandbath. 1·45	Sugar. Naked flame. 2·70; Sugar. Sandbath. 2·59		Sugar. Naked flame. 3·17; Sugar. Sandbath. 3·21
Blank	(0·14in1·99)	(0·14in2·05)	(0·14in4·01)	(0·14in3·85)	——	(·13 in 4·66 & in 4·74)
Correction for nitrite	+0·13	+0·03	+0·03	——	+·05	+·05
"X" nitrogen	0·04	0·09	0·22	0·11	——	0·17	0·21
Organic nitrogen by Kjeldahl, *with* reduction.	0·39	0·44	0·38	0·27	——	0·29	0·33
Organic nitrogen by Kjeldahl, *without* reduction:						
Taking ammonia by distillation	0·24	None (—0·01)	——	0·42
Oxygen absorbed from permanganate at 26·7° C. (80° F.): *at once.*	0·70	0·16	——	0·31
" " " *after four hours.*	2·99	1·10	——	1·16
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.) *at once.*	——	0·16	——	0·30
" " " *after four hours.*	——	0·84	——	0·38
Smell after incubation	——	Sweet and strong or fishy, but not offensive.	——	On border line; suspicious; sweet. } three observers.
Chlorine	5·30	7·70	——	7·98
Gases; Parts per 1,000, *by volume.*			This sample was very much blackened and had sucked in most of the mercury from the joint. *Very strongly putrid.* Not analysed.	
Oxygen (by cuprous chloride):				
(a) When sample was drawn	——	0·5		1·25
(b) " " analysed	——	Merest trace.		0·3 { two observers. }
Remarks	A very dilute sample (the filtered solution was colorless). Small amount of brown and grey sediment; very faint sewage smell.	Yesterday (24th January) I *think* this effluent was comparatively clear. To-day it was very dim and turbid, but with only a very little light brown flocculent sediment. The liquid had a brownish tinge. Smell	—— *Note.* This decomposition has gone further in 17 days than in 5 days at 80° F.	Slightly cloudy (cloudiness due mostly to lime), but with only a small quantity of light brown flocculent matter. Smell decidedly fishy, but quite good.
	doubt due to lime. distinctly fishy.	The turbidity is no		

CAMBRIDGE SEWAGE FARM, 1901.

Sewages and Effluents.

214 B Small Duplicate.	215 Screened and Settled Sewage (weak).	216 Effluent, corresponding to sewage No. 215 (clear, no smell).	217 Screened and Settled Sewage (strong).	218 Final Effluent, corresponding to sewage No. 217.
—	Monday, 28th January 1901, 11.15 a.m.	Monday, 28th January 1901, 12.50 noon.	Monday, 28th January 1901, 2.30 p.m.	Monday 28th January 1901, 4 p.m.
—	10·0° C. (50° F.)	6·1° C. (43° F.)	10·0° C. (50° F.)	6·1° C. (43° F.)
—	2·2° C. (36° F.)	3·3° C. (38° F.)	3·3° C. (38° F.)	0·6° C. (33° F.)
Jointed and Incubated 28th January. 11th February 1901.	—	—	—	—
	29th January 1901.	30th January 1901.	29th January 1901.	30th January 1901.
—	—	—	—	Turbid.
1·37	0·89	0·41	7·31	0·42
0·10	0·40	0·06	1·52	0·06
0·02	0·22	None.	0·12	heavy trace (·004)
0·87	0·26	1·36	not done.	1·05
			Sugar. Naked flame. / Sugar. Sandbath.	Sugar. Naked flame. / Sugar. Sandbath.
—	2·30	Flask broke.	11·41 / 11·63	1·59 / 1·62
—	(0·34 in 3·53)	—	(0·13 in 8·37 & in 8·53)	(0·13 in 2·44 & in 2·48)
—	+0·13	—	+ ·06 / + ·06	None.
—	0·53	—	2·46 / 2·68	0·06 / 0·09
—	0·93	—	3·98 / 4·20	0·12 / 0·15
—	—	None. (— ·15)	—	0·09 approx.
0·19	1·03	None.	3·48	0·15
—	4·92	0·39	17·81	0·57
—	—	0·11 } six days.	—	0·07
—	—	0·39 }	—	0·51
Sweet.	—	—	—	Sweet.
—	5·42	7·26	10·30	7·38
—	—	(?) 1·5	—	2·75
—	—	2·25, 1·8, 1·75 } Three observers.	—	about 1·0, 0·85, 0·9 } Three observers,
After incubation liquid was brownish, with brownish sediment. Sweet.	Fairly large amount of brownish-grey sediment. Soapy smell.	This looked an excellent effluent. Clear and colourless, with practically no sediment. Clean smell (slightly fishy-earthy).	Considerable brown deposit; slight sewage smell; alkaline.	This looked an excellent effluent. It was clear and with practically no suspended matter. Clean smell (slightly fishy-earthy).

CAMBRIDGE SEWAGE FARM, 1901.

Effluents.

No of Sample	No. 220		221		221
Nature of Sample	General Effluent. Cloudy and with a slight smell when drawn.		General Effluent. Sewage smell when drawn, and very cloudy.		Small Duplicate.
Drawn	Monday 4th February 1901, 12.15 noon.		Tuesday 5th February 1901, 11.30 a.m.		—
Temperature of sample	4·4° C. (40° F.)		4·4° C. (40° F.)		—
Temperature of air	0° C. (32° F.)		1·1° C. (34° F.)		—
If jointed or incubated	—		—		Jointed and incubated 6th February.
Analysed	5th February 1901.		6th February 1901.		12th February 1901.
Parts per 100,000, *by weight.*					
Ammoniacal nitrogen: (a) by Direct Nesslerization	Turbid.		Turbid.		—
(b) by Distillation	1·28		1·31		1·35
Albuminoid nitrogen	0·10		0·14		0·10
Nitrous "	0·04		0·08		0·10
Nitric "	0·84		0·64		0·54
Total nitrogen by Kjeldahl, *with* reduction, after nitrite correction.	Sugar. Naked flame. 2·53	Sugar. Sand bath. *2·62	1·5 grms. zinc; sugar. 2·43	3·0 grms. zinc; sugar. 2·46	—
Blank	(0·13 in 3·78)	(0·13 in 3·91)	(0·13 in 3·60)	(0·13 in 3·64)	—
Correction for nitrite	+ ·02	+ ·02	+ ·04	+ ·04	—
"X" nitrogen	0·27	0·36	0·26	0·29	—
Organic Nitrogen by Kjeldahl, *with* reduction.	0·37	0·46	0·40	0·43	—
Organic nitrogen by Kjeldahl, *without* reduction: Taking ammonia by distillation	0·23		0·14		—
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once.*	0·24		0·24		0·25
" " " *after four hours*	1·04		1·28		—
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once.*	0·21 } 6 days.		0·21		—
" " " *after four hours*	0·97 } 6 days.		1·03		—
Smell after incubation	Sweet.		Sweet.		Strong but not offensive.
Chlorine	8·06		7·94		—
Gases; parts per 1,000, *by volume.*					
Oxygen (by cuprous chloride): (a) when sample was analysed	Possibly a trace.		None.		—
Remarks	Opalescent, with a slight seaweed (?) smell. Very small amount of grey and brown sediment; alkaline. *Note.—Probably too high. Had to be distilled twice.		Opalescent, with considerable flocculent greyish sediment. Clean smell; alkaline. When drawing this sample, Mr. Kershaw described it as the worst effluent on the farm. The snow (0·05″ fall) had stirred up silt from the surface of plots at bottom of farm and down air vents, thus fouling the effluent.		After incubation the liquid was clear and almost colourless. Slight brown sediment, strong smell, but not offensive.

BURIED SLUDGE FROM CAMBRIDGE, 1901.

This sludge was buried 18 inches deep five years ago. A sample of it was dug up by Mr. Kershaw, and was received by me on 6th February 1901. Mr. Kershaw wrote:—"It is practically the same now as when dug in."

The nitrogen in it was determined by the *Kjeldahl* method.

——	15 February.	29 May.	10–26 June.
Nitrogen in moist sludge - - -	0·28%	0·47	0·48
Blanks - - - - - - -	(0·20 in 8·8)	(0·41 in 18·57)	(0·41 in 16·44)
Amounts of sludge taken (grms.) -	4·1822	4·7797	4·0868 grms.
Moisture at 100° C. - - - -	45·51%	34·90%	31·40%
Solid Matter - - - -	54·49 { 8·42% Volatile, 46·07% Non-vol.	——	——
Nitrogen (calculated on dry sludge)	0·51%	0·72%	0·70%

The sludge thus contained still an appreciable percentage of nitrogen. There were also present considerable quantities of iron and alumina and a large amount of lime (magnesia was not tested for). The lime was evidently present to a large extent as carbonate, as there was a brisk effervescence on treatment of the sludge with dilute hydrochloric acid. It also contained a distinct amount of sulphide.

When some of the sludge was heated in a subliming tube, strongly alkaline vapours were given off (probably pyridine derivatives, from their odour), which condensed in the cool part of the tube to an oily liquid. The sludge had an earthy smell and was grey outside and black inside (this due, no doubt, to sulphide of iron); it was of a clayey consistency.

To test its fermentability, two small portions of the sludge were placed in tubes which were then filled with distilled water and inverted over mercury. It was something like a couple of months before any gas came off, and very little even in three months. The addition of a few drops of settled sewage to another portion, treated similarly, had apparently little or no effect. These qualitative experiments are quite inconclusive, but they are sufficient to show that if this sludge is now fermentable it is only very slowly so.

The conclusion to be drawn here is that sludge should never be buried in masses, but should be thoroughly admixed with the soil in its upper layers.

CAMBRIDGE SEWAGE FARM, 1901.

River Water alone and admixed with Effluent.

No. of Sample	206	206	209a	214a
Nature of Sample	River Water above Effluent Outfall.	Small Duplicate transferred from large to small bottle as quickly as possible.	River Water above Effluent Outfall.	River Water 100 yards below Effluent Outfall.
Drawn	Thursday 10th January 1901, 12 noon.	—	Wednesday 16th January 1901, 12 noon.	Wednesday 23rd January 1901, 12·30 noon.
Temperature of sample	4·4° C. (40° F.)	—	2·2° C. (36° F.)	5·9° C. (42·5° F.)
Temperature of air	5·6° C. (42° F.)	—	4·4 C. (40° F.)	5·6° C. (42° F.)
If jointed or incubated	—	Jointed and incubated 11th January.	Jointed and incubated 17th January.	Jointed and incubated 24th January.
Analysed	11th January 1901.	1st February 1901.	8th Feb. 1901.	13th February 1901.
Parts per 100,000, *by weight.*				
Ammoniacal Nitrogen: (a) by direct Nesslerization	—	—	—	—
(b) by distillation	0·03	—	—	—
Albuminoid nitrogen	0·03	—	—	—
Nitrous ,,	None	0·56	0·56	None.
Nitric ,,	0·55			0·60
Total nitrogen by Kjeldahl, *with* reduction (no correction for nitrite).	0·62	—	—	—
Blank	(0·34 in 1·25)	—	—	—
"X" nitrogen	0·01	—	—	—
Organic nitrogen by Kjeldahl, *with* reduction.	0·04	—	—	—
Organic nitrogen by Kjeldahl, *without* reduction: Taking ammonia by distillation	0·06	—	—	—
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once.*	0·03	—	—	0·03
,, ,, ,, *after four hours*	0·53 ($4\frac{1}{2}$ hours.)	—	—	—
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once.*	0·10	—	—	—
,, ,, ,, *after four hours*	0·22	—	—	—
Smell after incubation	Sweet.	Slightly fishy-earthy.	—	No smell.
Chlorine	Not done; sample accidentally thrown away.	—	—	—
Gases; Parts per 1,000, *by volume.*				
Oxygen (by cuprous chloride): (a) When sample was drawn	—	—	7·0	*6·0
(b) ,, ,, ,, analysed	6·25, 6·25 Two observers.	1·60, 1·75 Two observers.	4·0, Fully 4·0 Two observers.	About 0·5 Two observers.
Remarks	Slightly turbid, from a small but appreciable amount of sediment. No smell. A great deal of lime in solution, but only a rather small amount of sulphate; no iron, or merely a trace.	Till within a few days of 1st February this bottle was inside incubator and then on the top. After incubation the water was clear and colourless, with a slight brownish flocculent sediment. Slight but distinctly fishy-earthy smell.	When drawn this sample was clear and the river normal. On 8th February the incubated sample was clear and colourless, with a few small brown specks. Slight earthy smell.	After incubation this sample was colourless, with practically no sediment. No smell. The incubation has practically exhausted the oxygen here. * 6·5, 90 yards lower down the stream.

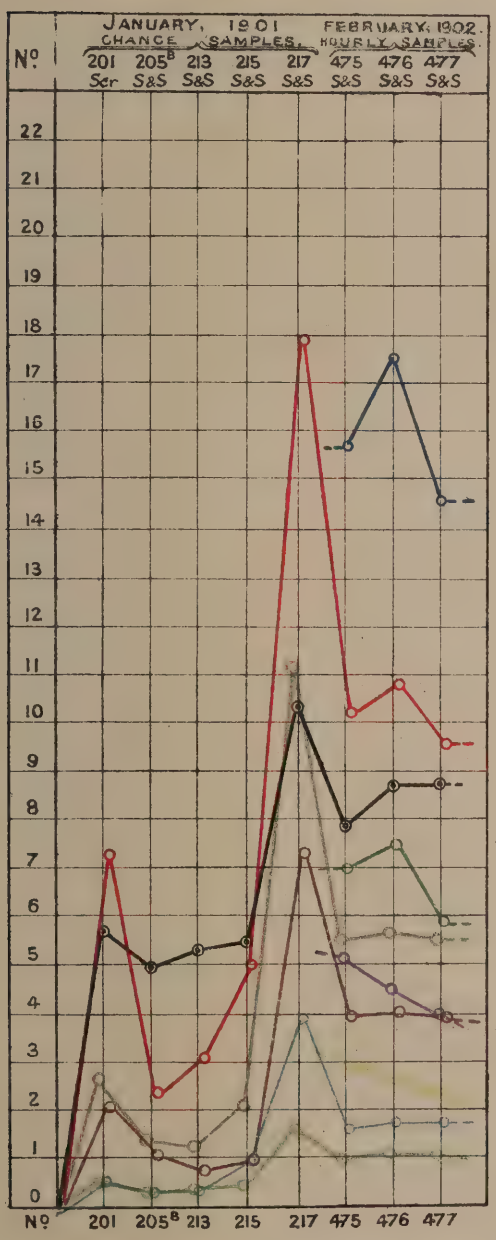
CAMBRIDGE SEWAGE FARM, 1901.

River Water alone and admixed with Effluent.

222	223	223	219	219
River Water above Effluent Outfall. River normal.	River Water containing effluent, taken 10 yards below effluent outfall.	Small Duplicate.	Subsoil Water. Taken at the outcrop of the Gault from a land drain.	Large Duplicate.
Wednesday, 6th February 1901, 12 noon.	Wednesday 6th February 1901, 12.15 noon.	—	Wednesday, 30th January 1901, 11.30 a.m.	—
1·1° C. (34° F.)	1·1° C. (34° F.)	—	6·7° C. (44° F.)	—
2·2° C. (36° F.)	2·2° C. (36° F.)	—	2·2° C. (36° F.)	—
—	—	Jointed and incubated 7th February.	—	Jointed, and left at atmospheric temp., 31st January.
7th February 1901.	7th February 1901.	15th February 1901.	31st January 1901.	28th March 1901.
Turbid.	—	—	Too small to estimate.	—
0·019	0·19	—	0·0008	—
0·037	0·03	—	0·015	—
None.	None.	0·13 approx.	None.	None.
0·45	Spoilt.	0·51	0·91	0·95
1·5 gram. zinc; sugar. 0·63 / 3 gram. zinc; sugar. 0·57	0·76	—	Sandbath. 0·99	—
(0·13 in 1·05 & in 0·96)	(0·20 in 1·31)	—	(0·13 in 1·56)	—
0·12 / 0·06	(?)	—	0·06	—
0·16 / 0·10	(?)	—	0·08	—
0·10	None (— 0·06)	—	0·043 approx. (rather turbid.)	—
0·08	None.	—	Too little to estimate.	0·07
0·42	0·20	—	0·12	0·35
0·16	0·33	—	0·03	—
0·32	0·43	—	0·09	—
Sweet.	Sweet.	Earthy.	Slight earthy.	No smell.
2·06	2·84	—	1·60	—
7·0	5·5	—	3·5	—
Not noted on 7th.	6·8, 6·6, 6·2 three observers.	2·7 Two observers.	2·7–2·8, 2·8, 2·8 three observers.	2·4, 2·2 Two observers.
Colourless, with a very small amount of brownish sediment. No smell. Alkaline. This sample is not quite so good as No. 206.	Colourless but very slightly turbid. Some light brown sediment. No smell. Alkaline.	After incubation this was a colourless clear liquid, with a small amount of light brown sediment. Earthy smell.	We got two bottles of this. One contained much more sediment (like sand) than the other, though not really much. The clearer sample containing but little sediment was analysed, keeping the sediment out of the analysis as far as possible. This was a beautiful sample, clear and colourless. No smell. Much lime in solution; a considerable amount of sulphate; no appreciable iron.	Clear and colourless, but in this sample there was a considerable amount of light brown sediment (more than in the sample done on 31st January). Presumably the clear supernatant water was again analysed here.

Diagram No. 13.

CAMBRIDGE SEWAGE FARM.
SEWAGES, CURVES.



Nature of Sewage

Scr = *Screened*

S&S = *Screened & Settled*

REFERENCE

Parts per 100.000, by Weight.

Albuminoid Nitrogen ..... *Shewn thus*

Organic Nitrogen by Kjeldahl, with Reduction .....

Ammoniacal Nitrogen .....

Total Nitrogen by Kjeldahl, with Reduction .....

"Oxygen absorbed" from Permanganate at 26·7°C (80°F.) in four hours .....

Chlorine (Combined) .....

Solids in Suspension (Gravimetrically) (Scale divided by 10) .....

Cellulose .....

Cellulose (still containing fat) .....

Parts per 100.000. by Volume.

Solids in Suspension (by Centrifuge) (Scale divided by 10)

Note

Figures in the Vertical line represent "Parts per 100.000."

Figures in the Horizontal line represent the numbers of the Samples analysed.

A dotted line is used when there is a break in the curve.

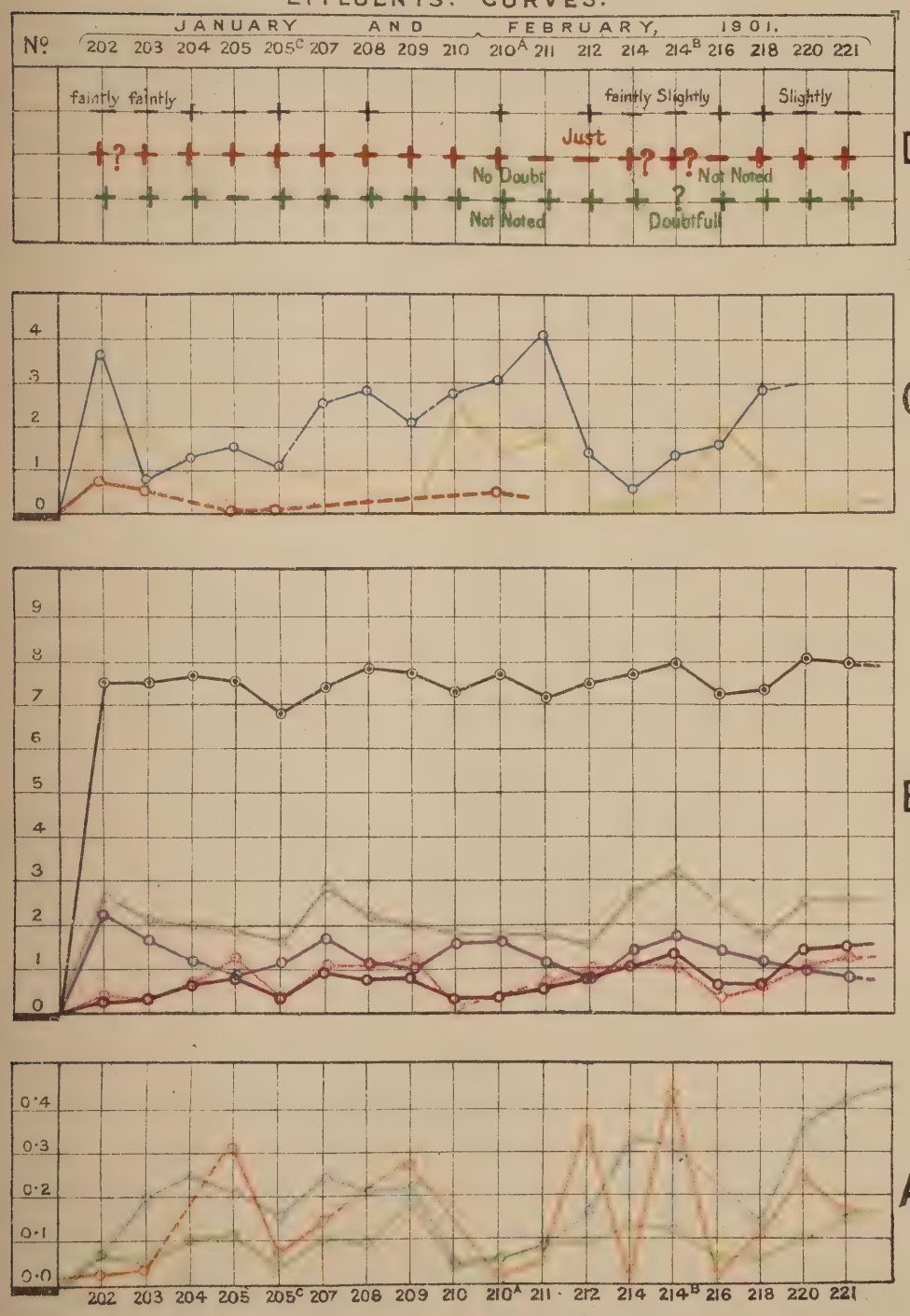
3332 8.02.

Weller & Graham. Ltd Litho. London.

Diagram No 14.

CAMBRIDGE SEWAGE FARM.

EFFLUENTS. CURVES.



REFERENCE

Smell of Samples when drawn Shewn thus + —

Scudder's Incubation Test + —

Incubation test as judged by Smell + —

Parts per 1,000, by Volume (C.C. per Litre)

Dissolved Oxygen when sample was drawn Shewn thus ———

Dissolved Oxygen when sample was analysed

Dissolved Oxygen in duplicate sample after incubation.

Parts per 100,000, by Weight.

Ammoniacal Nitrogen. Shewn thus ———

Total Nitrogen by Kjeldahl, with Reduction.

Nitric + Nitrous Nitrogen (together)

"Oxygen absorbed" from Permanganate at 26·7°C (80°F.) in four hours.

Chlorine (Combined)

Parts per 100,000, by Weight.

Albuminoid Nitrogen Shewn thus

Organic Nitrogen by Kjeldahl, with Reduction.

Organic Nitrogen by Kjeldahl, without Reduction.

Note

Figures in the Vertical line represent "Parts per 100,000."

Figures in the Horizontal line represent the numbers of the Samples analysed.

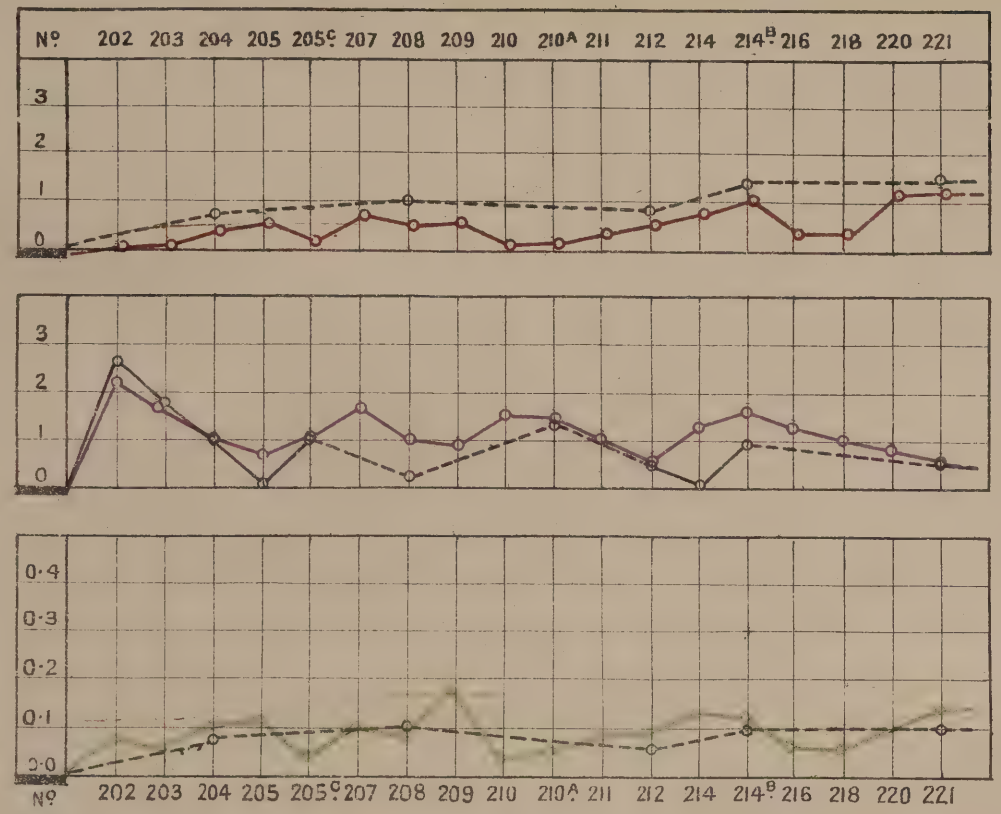
A dotted line is used when there is a break in the curve.

3332 . B . 02.

Diagram No. 15.

CAMBRIDGE SEWAGE FARM. EFFLUENTS.

Curves of Duplicate samples of Effluent before & after Incubation: showing the changes in amount of Ammoniacal, Albuminoid and Nitric + Nitrous Nitrogen.



REFERENCE

Parts per 100.000, by Weight.

C — *Ammoniacal Nitrogen before incubation: Shewn thus* ——
" " " *after* " " ——

B — *Nitric + Nitrous Nitrogen (together) before incubation,* ——
" " " " " " " *after* " " ——

A — *Albuminoid Nitrogen before incubation* ——
" " " " " *after* " " " ——

Note

Figures in the Vertical line represent "Parts per 100.000."

Figures in the Horizontal line represent the numbers of the Samples analysed.

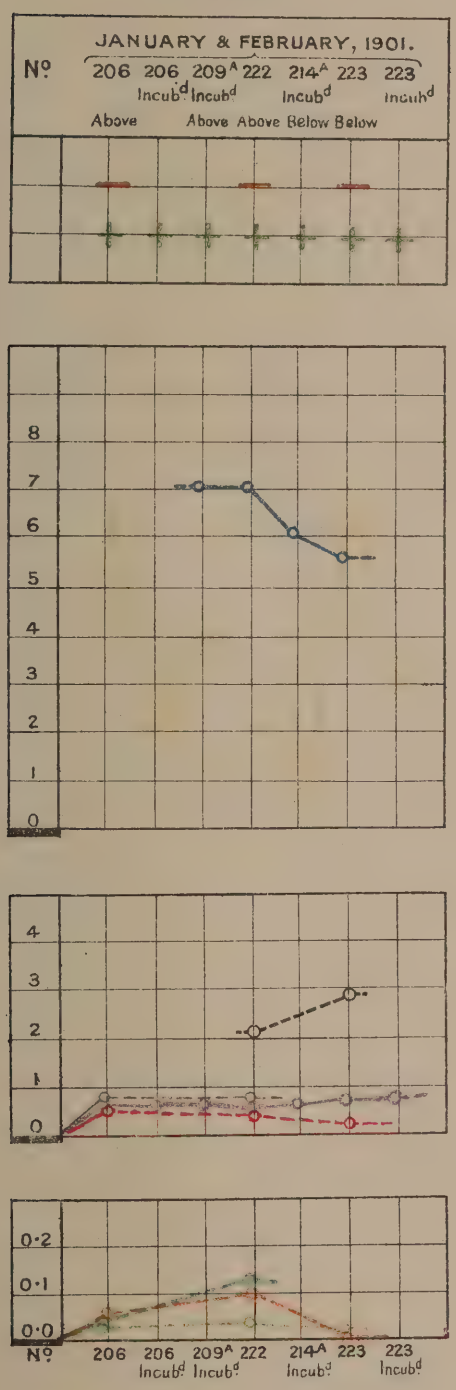
A dotted line is used when there is a break in the curve.

3332. 12. 02.

Weller & Graham Ltd Litho. London.

Diagram No. 16.

CAMBRIDGE SEWAGE FARM.
RIVER WATER.
CURVES.



Note
"Above" indicates a sample taken above Effluent Outfall.
"Below" " " " " below " " " "

REFERENCE

Scudder's Incubation Test + −

Incubation test as judged by Smell + −

Note
"Incubated" Indicates a sample jointed and allowed to stand for five days or longer at a temperature of 26.7°C (80°F.)

Parts per 1000, by Volume (C.C. per Litre.)

Dissolved Oxygen when sample was drawn Shewn thus

Dissolved Oxygen when sample was analysed

Parts per 100.000. by Weight.

Total Nitrogen by Kjeldahl, with Reduction. Shewn thus

Nitric + Nitrous Nitrogen (together).

"Oxygen absorbed" from Permanganate at 26·7°C (80°F.) in four hours.

Chlorine (Combined).

Albuminoid Nitrogen. Shewn thus

Organic Nitrogen by Kjeldahl, with Reduction.

Organic Nitrogen by Kjeldahl, without Reduction.

Note.
Figures in the Vertical line represent "Parts per 100.000".
Figures in the Horizontal line represent the numbers of the Samples analysed.
A dotted line is used when there is a break in the curve.

3332.8.02

Weller & Graham: Ltd Litho. London.

CROYDON (BEDDINGTON) SEWAGE FARM.

Chemical Report.

1. Situation of farm—Beddington, about three miles from Croydon.
2. Total acreage of farm—673·5.
3. Total irrigable area—420 acres.
4. Average area irrigated at one time—70 acres.
5. Population draining to farm—100,000.
6. Population per acre irrigated—238.
7. Gallons of sewage per head per day—40 gallons.
8. Dry weather flow of sewage per 24 hours—4,000,000 gallons.
9. Gallons of sewage treated per acre per 24 hours—57,100 gallons.
10. Gallons of sewage treated per acre per 24 hours, on the assumption that each acre of the irrigable area is under sewage all the time—9,500.
11. Character of the sewage—Almost purely domestic.
12. Method of treatment—(*a*) Croydon: Screening, surface irrigation and a little filtration. (*b*) Norbury: As above, but slight settlement in tanks in addition.
13. General character of the soil and subsoil—Gravelly loam overlying gravel and sand.
14. Separate or combined sewerage system—Partially separate.
15. The final effluent is discharged into—River Wandle.
16. Number of years farm in operation (before 1900)—39 years.

CROYDON (BEDDINGTON) SEWAGE FARM.

Beddington Farm is of particular interest, both because of its having been sewaged for the last forty years, and also from having been under observation in 1868-9 by the Rivers Pollution Commission for fully a year (Vol. I., First Report, pp. 87-89). On nearly every occasion when samples of effluent were drawn at that time, they were found to be of excellent quality.

The area actually irrigated at Beddington is 420 acres, of which about one-sixth is under sewage at a time, the sewage being run on for 24 hours continuously. (It will be noted that this ratio is small as compared with that at some of the other farms.) The whole of the irrigable area is under grass or crop at one time or another in the course of the year.

Mr. Kershaw states in his report* that only about 100 acres of the farm are underdrained, *i.e.*, less than a quarter of the whole, and that the distances between the drains are usually great. In depth the drains vary from 4ft. to 9ft. (average about 6ft.). Although, therefore, the soil is of an open, porous nature, the farm may be taken in the main as a good example of a surface irrigation farm, though here again the effluents are to some extent filtration effluents also. The sewage, which is previously screened, and partly settled to a small extent only, passes over three—and sometimes even four—separate plots of ground. The *whole* of the storm water is treated on the farm, and all the screenings, together with what settled sludge there is, are dug into the soil (*cf.* Engineering Report). Mr. Kershaw says that there is not much subsoil water on the farm.

* Part IV. Engineering and Practical Report.

Soil and Subsoil.

To quote from the Engineering Report :—"The surface soil consists in most parts of from 12in. to 18in. of soil, varying from loam interspersed with gravel to a somewhat lighter soil. The subsoil varies, but it is chiefly gravel and sand of a depth from 6ft. to 12ft. Iron pan (which is more or less impervious) occurs in parts."

The mechanical composition, etc., of these is given in the following table :—

Name of Fraction.	Surface Soil per cent.			Subsoil per cent.		
	Not Ignited.	Ignited.	Difference.	Not Ignited.	Ignited.	Difference.
Gravel and stones (say, above 8 m.m. diameter in the soil, and 30 m.m. to 8 m.m. in the subsoil) - - - - -	22·67	22·67	—	*57·47		
Fine "gravel" (above 2·0 m.m. diameter)	11·34	10·97	0·37	19·28		
Coarse "sand" („ 1·0 m.m. „)	0·88	0·80	0·08	2·01		
Coarse "sand" („ 0·5 m.m. „)	0·63	0·59	0·04	1·14		
Medium "sand" („ 0·25 m.m. „)	1·75	1·70	0·05	2·56		
"Sand" (0·25 to 0·05 m.m.) - - -	40·16	39·14	1·02	14·16		
"Silt" (0·05 to 0·01 m.m.) - - - -	14·32	12·53	1·79	0·98		
"Dust" (0·01 m.m. and below, which settles from water in 24 hours) - - - -	6·88	5·56	1·32	2·48		
"Clay" (*i e.*, the still finer residue precipitated from water by dilute nitric acid) -	0·71	0·57	0·14	0·25		
Loss on ignition (separate determination) -		5·46				
	99·34	100·09	4·81	100·33		
Real specific gravity of soil dried at 110° C.	2·512			2·490		
Apparent specific gravity - - - -	1·414			1·843		
Number of particles in 1 gramme of the ignited soil or subsoil (approx.) - -	368,297,690			160,510,970		
Number of particles in 1 c.c. of the ignited soil or subsoil (approx.) - - - -	520,775,170			295,828,280		
Weight of water retained by 100 grammes of the soil when fully drained - - -	39·5			10 6		
Parts per 100,000.						
Lime dissolved by water in 24 hours - -	0·029			0·026		
Lime dissolved by water, saturated with carbonic acid, in 48 hours - - -	0·215			0·268		

For a discussion of the figures given in this table, the reader is referred to the Section upon Soils, page 275.

* This subsoil gave very little loss on ignition ; so, for purposes of calculation, the ignited values are assumed to be the same as the unignited.

Volume treated per acre, etc.

The Beddington sewage contains only about 2 per cent. of laundry, brewery and butchers' refuse, and may therefore be taken as domestic sewage. The average dry weather flow is 4,000,000 gallons per 24 hours for a population of 100,000, which gives 40 gallons per head of population, and 238 persons per acre irrigated. The water supply being about 28 gallons per head, the remaining 12 gallons must come from subsoil water entering the sewers, well water, and some brewery refuse, or :—

Sewage - - - - - -	70 per cent.
Subsoil water, etc. - - - -	30 ,,

The average area irrigated at one time is about 70 acres, hence each acre treats 57,000 gallons in 24 hours. But, making our usual assumption *for purposes of comparison* that the whole irrigable area is under sewage continuously, *then one acre at Beddington treats* 9,500 *gallons per* 24 *hours all the year round.* In times of storm this volume is, of course, greatly increased (*cf.* Engineering Report). Apart from storm water, a medium amount of organic matter is treated per acre.

Four visits were paid to Beddington, viz., in February and October, 1900; October, 1901 ; and January, 1902.

Nature of Sewage (*Diagram No.* 17).

As already stated, this is practically all domestic. The whole of it is screened, and—in addition—one quarter of it passes through small settling tanks, in which, however, the settlement is very inadequate. It arrives at the farm well broken up, as a rule.

Fourteen samples in all were analysed, viz., seven chance samples, and seven sets of hourly samples drawn *in equal quantities* every hour of the twenty-four. The chance samples were taken in February and October, 1900, and the hourly ones in January, 1902.

While the hourly samples will be mainly relied upon for any approximate calculations, it must not be forgotten that they will represent a distinctly weaker sewage than a true average taken according to rate of flow. Some rain fell on two of the days on which they were drawn, but probably not enough to materially affect the composition of the two samples in question (Nos. 443 and 446); if in one respect these were weakened, they would contain more than their normal share of suspended solids, washed out of the sewers.

Taken all over, the chance samples were the stronger, which is not surprising, as they were all drawn between 11 and 12.15 in the forenoon, when the Beddington sewage is probably at about its strongest. Nos. 149 and 152 were screened and settled, the others screened only. They were very uneven in composition. The hourly samples (screened), on the other hand, were tolerably uniform, excepting as regards suspended solids and "oxygen absorbed," this evidently arising in part from the rainfall already referred to.

Of the chance samples, the first five contained either a moderate or a large amount of suspended solids (as judged by appearance), the last two (161 and 164A) but little. All that were tested were alkaline in reaction, and all had a "sewage" smell, though in Nos. 149 and 152 it was conjoined with a smell of peppermint. In the hourly samples the suspended matter varied appreciably, being only moderate in quantity on the whole, the reaction was alkaline, and the smell—which varied much in character (see notes to figures of analysis)—not by any means very pronounced.

As regards temperature, the chance samples varied between 9·4 deg. and 15·5 deg. C. (49 deg. and 60 deg. F.), the two drawn in February being lower by 5 deg. or 6 deg. C. than those drawn in October.

The following is a summary of the more important analytical results :—

	Average.
Total Nitrogen—(*a*) 7 chance samples (6·82 to 13·42) - - -	9·50
(*b*) 7 sets of hourly samples (6·42 to 7·59) - - - -	7·18
Ammoniacal Nitrogen—(*a*) 6 chance samples (4·15 to 9·71) - -	7·34
(*b*) 7 sets of hourly samples (4·18 to 5·11) - - - -	4·50
Total Organic Nitrogen—(*a*) 5 chance samples* (2·03 to 4·06) -	3·37
(*b*) 7 sets of hourly samples (1·31 to 2·88) - - - -	2·07
Albuminoid Nitrogen—(*a*) 6 chance samples (0·99 to 2·36) - -	1·72
(*b*) 7 sets of hourly samples (0·59 to 1·12) - - - -	0·91
"*Oxygen absorbed*" at 26·7° C. (80° F.) *in* 4 *hours*—(*a*) 7 chance samples (7·91 to 18·73) - - - - - - - -	13·70
(*b*) 7 sets of hourly samples (7·85 to 17·45) - - - -	12·48
Chlorine—(*a*) 6 chance samples (5·70 to 10·50) - - - -	8·15
(*b*) 7 sets of hourly samples (7·86 to 9·22) - - - -	8·34
Chlorine in Water Supply - - - - - - - -	1·3
Ratio of Ammoniacal Nitrogen to Chlorine—7 sets of hourly samples (1 : 1·76 to 1 : 2·00) - - - - - -	1 : 1·86
Ratio of Ammoniacal Nitrogen to Chlorine, after deducting the Chlorine of the Water Supply—7 sets of hourly samples (1 : 1·47 to 1 : 1·71) - - - - - - - -	1 : 1·56
Solids in Suspension—7 sets of hourly samples (21·2 to 53·0) -	34·5
Solids in Suspension by Centrifuge (*Volumes*)—7 sets of hourly samples (173 to 356) - - - - - - - -	218
Ratios of Solids in Suspension to Centrifuge Solids - 1 : 6·7, 1 : 5·5, 1 : 8·2, 1 : 4·8, 1 : 4·9, 1 : 8·2, 1 : 8·1 -	1 : 6·6
Cellulose still containing fat, 7 sets of hourly samples (one extraction with dilute alkali and one with dilute acid) (3·92 to 12·80) - - - - - - - -	7·47
Ratios of Cellulose still containing fat to Suspended Solids in 7 sets of hourly samples - - - 1 : 4·1, 1 : 4·7, 1 : 4·0, 1 : 5·8, 1 : 6·2, 1 : 5·4, 1 : 3·6 -	1 : 4·8

The estimations of cellulose proper, by extracting the above with ether, were not made in this case.

The analytical figures and curves thus show very great variations between the individual chance samples, but comparative evenness in the hourly ones, excepting as regards suspended solids and "oxygen absorbed." In every case in the chance samples the high "oxygen absorbed" figure goes along with what were evidently large quantities of suspended solids; but this by no means follows in the hourly samples. These variations and inequalities are no doubt mainly due to the fact that the *whole* of the storm water is treated at Beddington, and that there is but little preliminary settlement of the sewage.

The total nitrogen in the chance samples averages 9·50, and in the hourly ones 7·18; the organic nitrogen (in 5 chance samples) averages 3·37, and in the hourly

*Omitting No. 40

samples 2·07; the respective figures for "oxygen absorbed" in the 7 chance and 7 hourly samples are 13·70 and 12·48; and the suspended solids in the hourly samples average 34·5. The sewage may thus be classed as a moderately strong one.

Excepting in Sample No. 40 (which probably contained nitrate, and should have been tested for this), the four curves for albuminoid nitrogen, total organic nitrogen, ammoniacal nitrogen and total nitrogen follow one another with fair regularity. The total nitrogen, both in the chance and hourly samples, is approximately three times the organic nitrogen, and the organic is fully twice the albuminoid.

As only two estimations of organic nitrogen were made by the method of Kjeldahl *without reduction*, no comparison can be drawn here between it and the other method.

The Average Ratio between Albuminoid Nitrogen and "Oxygen absorbed" in the six chance samples is 1 : 8·9, and in the seven sets of hourly samples 1 : 13·7; but in the chance samples the ratio is a very uneven one, and in the hourly it is also uneven.

The ratio between the figures for organic nitrogen and "oxygen absorbed" in the five chance samples is 1 : 4·1; in the seven sets of hourly samples, on the other hand, it is 1 : 6·0. Why there should be such a difference between these ratios here it would be difficult to say, unless we refer it again to the storm water. If we take the two together, the ratio is 1 : 5·2, which agrees approximately with that for other domestic sewages, though tending to be high.

In five out of the seven sets of hourly samples there were appreciable or large quantities of nitrate present, a proof of the infiltration of subsoil water into the sewers. The chance samples were, unfortunately, not tested for nitrate. Judging from analogy, it was probably present in some of them, in which case the figures given for the "x" nitrogen and organic nitrogen in those sewages will be higher than the reality.

In these sewages, both chance and hourly samples, the *"oxygen absorbed"* curve stands practically by itself. It bears no relation to any of the other curves, excepting to the curve for cellulose still containing fat (omitting sample No. 445).

The *chlorine* curve in the chance samples is irregular, and no connection can be traced between it and any of the others. In the hourly samples it follows very fairly the curves for total and for ammoniacal nitrogen. In the case of average samples of the Beddington sewage, therefore, the chlorine gives a good indication of the (nitrogenous) strength; but storm water would be bound to disturb this.

No estimations of *suspended solids* were made in the chance samples, but—judging from their appearance—large quantities were present in some of them. The variations in suspended solids in the hourly samples have been already referred to.

In the hourly samples the differences in the ratios between the *suspended solids* estimated (*a*) gravimetrically and (*b*) volumetrically by the centrifuge are too great for this ratio figure to be of much use, the extremes being 1 : 4·8 and 1 : 8·2. Nor can I offer any suggestion, other than the reference to storm water and to non-settlement, as to why this should have been so. Before, therefore, the centrifuge could be used as an approximate test for the suspended solids in the Beddington sewage, further estimations would have to be made.

Unfortunately, no estimations of true cellulose were done here—only of cellulose still containing fat, as obtained by one treatment of the sewage with dilute alkali and one with dilute acid; and here again the ratios are not uniform (limits 1 : 3·6 and 1 : 6·2), the average being 1 : 4·8.

*First Field Effluents.** (*Diagram No.* 18.)

Only *three* first field effluents, drawn in February and October, 1900, were examined. The first of them, No. 37, was practically a sewage; when it was drawn the field was partially ice-bound and covered with snow. The temperature of this effluent was only 1·1 deg. C. (34 deg. F.). The next sample, No. 41, was of wonderfully good quality for a first field irrigation effluent (off rye-grass), and it kept sweet upon incubation because of its comparatively large reserve of nitrate (it may possibly have

* Mr. Kershaw says that nearly all of the first, second, and third field effluents are *surface* effluents.

extracted some which had been storing up in the ground during a short rest, but at the same time it is noteworthy that the ammoniacal nitrogen in this sample, relatively to the total nitrogen, was low). The temperature of this sample, drawn only a week after No. 37, was 8·3 deg. C. (47 deg. F.)—a striking instance of the variation in temperature upon a surface irrigation farm.

The third sample, No. 150, was drawn in October, 1900, and had a temperature of 10·6 deg. C. (57 deg. F.). It was considerably purified, but, of course, not good.

It will be seen that all the curves of these effluents, excepting, of course, the nitrate curve, are of the same type, though not proportionate to one another.

In Nos. 37 and 41 the determination of organic nitrogen by Kjeldahl (*a*) with reduction and (*b*) without reduction agreed very well; in No. 150 only the former method was employed.

Second Field Effluents. (*Diagram No.* 18.)

Five second field effluents were analysed, two of them in double duplicate, after jointing and incubation. Of these, Nos. 38 and 42 were drawn in February, 1900, and their temperatures were 4·4 deg. and 7·7 deg. C. (40 deg. and 46 deg. F.). Nos. 151, 153 and 156 were drawn in October of the same year, and varied in temperature between 10 deg. and 15 deg. C. (50 deg. and 59 deg. F.).

These effluents were either opalescent or nearly clear, and, excepting No. 38, in which a good deal of bluish-grey flocculent matter was present, they contained very little suspended solid of any kind; in this respect, therefore, the surface purification over two fields had been very efficient. Excepting possibly No. 153 (which was doubtful), they all had a clean smell when analysed, though this was masked by peppermint in No. 151; and those tested were alkaline, and contained much lime and a good deal of sulphate in solution.

Nos. 38 and 42, neither of which (especially No. 38, drawn when the field was partially ice-bound and covered with snow) was good as respected dissolved organic matter, kept on incubation; but this was due to their containing between one and two parts of nitric nitrogen (*cf.* remarks on first field effluent, No. 41, above). The others contained no nitrate, or practically none, and became putrid upon incubation.

Nos. 42 and 156 were well aerated when they came to be analysed, but there was no dissolved oxygen in the others. No. 153 contained only 1 c.c. per litre when drawn, which, for a surface irrigation effluent, showed that oxidation was proceeding rapidly at the time. Mr. Kershaw states in his Notes, however, that this land had had barely three days' rest since the previous sewaging.

The figures for albuminoid and for total organic nitrogen were high for effluents, those for "oxygen absorbed" relatively less. The curves for chlorine, total nitrogen, ammoniacal nitrogen and albuminoid nitrogen follow one another closely (excepting in No. 42), but the "oxygen absorbed" curve does not bear much resemblance to these.

In two out of four determinations the figures for total organic nitrogen obtained by Kjeldahl (*a*) with reduction and (*b*) without reduction agreed, but in the other two they did not.

Without going into further detail regarding these few samples, it is evident from the above results that irrigation over two fields, with the quantity of sewage treated at Beddington, is insufficient for purification. It may, however, be noted that the relative purification effected in the comparative* samples, Nos. 37 and 38, 150 and 151, appeared to be pretty equal, as will be seen by a glance at the curves.

* Those samples were drawn as comparative, but to get really comparative (chance) samples on a farm is an almost impossible task.

Third Field: Final and General Effluents. (*Diagram No.* 19.)

Of the final effluents two—Nos. 153 and 156—were over two fields only; they have, therefore, been included in the curves of the second field effluents, as well as in those of the final effluents.

Sixteen samples were examined, nine of them in duplicate after jointing or incubation. Five of the sixteen, viz., Nos. 44, 369, 376, 380 and 384, were general effluents, the others being final effluents from definite plots of ground. *They may be taken as being nearly all surface effluents.* They were drawn in February, 1900; October, 1900; and October, 1901.

The *temperatures* of those samples varied between 1·1 deg. and 16·6 deg. C. (34 deg. and 62 deg. F.)—a sufficient indication of their being surface effluents. At the same time, if we leave out Nos. 39, 39A and 43, drawn in February, 1900 (whose temperatures were 2·2 deg., 1·1 deg., and 7·2 deg. C.), the variations in temperature among the other thirteen were only from 10 deg. to 16·6 deg. C. (50 deg. to 62 deg. F.); of course, they were all drawn in the month of October, either in 1900 or 1901.

The following figures show some of the more important average analytical results from the examination of 15 to 16 effluents, details being given in the annexed Tables of Analysis and Curves:—

	Average.
Total Nitrogen (1·02 to 3·49) - - - - -	2·20
Ammoniacal Nitrogen (0·23 to 3·10) - - - - -	1·48
Albuminoid Nitrogen (0·06 to 0·23) - - - -	0·14
Total Organic Nitrogen (0·09 to 0·55) - - -	0·26
Nitric + Nitrous Nitrogen together (0·03 to 1·43) -	0·37
"Oxygen absorbed" from permanganate at 26·7° C. (80° F.) *in 4 hours* (0·90 to 2·09) - - -	1·41
Incubator Test (as judged by smell) - - -	73 % passed. (15 samples tested).

These effluents varied a good deal in appearance, some of them being clear and almost colourless, and to all appearance excellent effluents; others of a yellowish to brownish tint, with but a very small amount of suspended solid of one kind or another; while in others the liquid was turbid, with very considerable quantities of suspended solids. Three-fourths of them may, however, be taken as very free from matter in suspension. Nos. 39A and 44, for instance, belong to the category of turbid samples; they were drawn during rain—*i.e., contained much storm water.* No. 380, also turbid, showed no precipitated sediment, but a large quantity came down in the centrifuge. This last sample was not drawn during rain, but was insufficiently purified.

Those few notes with regard to the appearance of the Beddington final and general effluents are, I think, sufficient in themselves to indicate the difficulty of treating largely fluctuating volumes of liquid (sewage plus storm water) by surface irrigation.

Three-fourths of the effluents had a good clean smell when they came to be analysed, but No. 153 (a bad sample) had a faint sewage (?) smell, No. 380 (also bad) a fishy smell, and Nos. 39 and 44 (fair) a fishy-earthy smell. All that were tried for reaction were alkaline, and the three tested qualitatively showed much lime and a good deal of sulphate in solution.

The analytical tables and curves show that the effluents varied appreciably in quality, the few samples drawn in February being rather stronger than those drawn in October.

The *dissolved oxygen* present when the samples came to be analysed varied very much, but half of the effluents were then well aerated, *i.e.*, contained from 4 c.c. upwards of dissolved oxygen per litre—a point in their favour. (Properly purified surface irrigation effluents ought, of course, to be well aerated at the time of drawing).

The free *carbonic acid* in the six samples boiled out varied between 21·05 c.c. per litre in No. 43, and 38·56 c.c. in No. 155, *i.e.*, the quantities were not very large, as was to be expected in surface effluents. No. 155 was what might be called a "border line" effluent, and Mr. Kershaw has noted that it may have been affected injuriously by the lifting of a sluice gate.

In seven out of the eight cases tested, the smell of the effluents when drawn was an indication of their keeping property.

The *ammoniacal nitrogen* in fifteen effluents varied between 0·23 and 3·10, which are very wide limits, the average being 1·48; this is equal to about two-thirds of the total nitrogen.

The *albuminoid nitrogen* in fifteen effluents varied between 0·06 and 0·23 parts per 100,000, the average being 0·14.

With regard to "*oxygen absorbed*," this varied in fifteen effluents between 0·90 and 2·09, average 1·41.

Incubation. Mr. Scudder's incubator test was rather more stringent than the incubation test as judged by smell, but on the whole they agreed very fairly; that is to say, there was agreement in nine cases out of fifteen, and almost agreement in three of the remaining six*.

The incubation smell test condemned four out of fifteen, and of the remaining eleven two are classed as doubtful.

The *total nitrogen* in sixteen effluents varied very considerably—*i.e.*, between 1·02 and 3·49. The average was 2·20.

The *total organic nitrogen* was small, varying as it did in sixteen effluents between 0·09 and 0·55, with an average of 0·26—*i.e., it was almost double the albuminoid nitrogen.* The two samples showing the largest quantities of organic nitrogen, No. 39A and 380, were both turbid ones. Comparing the results of the incubation test as judged by smell with those rather small figures for organic nitrogen, one is obliged to conclude that the organic matter which is left in some of the Beddington effluents is *relatively* of a somewhat putrescible nature.

In nine of the effluents comparative estimations of organic nitrogen were made by the two Kjeldahl methods—*i.e.*, with and without reduction. In six of these there was good agreement, and in three disagreement. In one of these three cases, No. 43, the figure given by the method without reduction was obviously the more correct; while in the other two, Nos. 155A and 160, the method with reduction was preferable.

Two of the effluents (Nos. 153 and 380, both bad samples) contained no *nitrite nitrogen* when analysed; thirteen contained from 0·02 to 0·05 parts, and in No. 44 there was 0·07 part per 100,000. In only one case, therefore, was the quantity at all appreciable.

The *nitric* (including nitrous) nitrogen varied between 0·03 and 1·43, and only exceeded one part per 100,000 in one sample (No. 43, not really a good sample), while in four others (Nos. 153, 155, 160 and 380) it was *nil*, or practically *nil*. The average for fifteen effluents is only 0·37—a very low figure as compared with that for the total nitrogen. Further, in respect of degree of nitration, there is no appreciable difference between the general final effluents on the one hand and the special final effluents on the other. Still, although the absolute amount of nitrate was so small, it was not reduced to any extent upon jointing or incubating the six samples, Nos. 44, 157, 159, 369, 376 and 384. Of these six, four were general effluents, which thus show to some advantage over the others. The other three samples incubated (Nos. 153, 155 and 380) had no nitrate to lose.

---

* It was only in the last four samples shown on the curves that the amount of Nitrite after incubation was noted. It is therefore assumed generally that it did not exceed the Nitrite present before incubation. Further, Sample No. 159 is taken as good by Mr. Scudder's test.

The *ratio of oxidised to unoxidised nitrogen* (taking the unoxidised = 1) varies in fifteen effluents between 0·01 : 1 and 2·2 : 1 ; but the next highest ratio is only 1·3 : 1. There are discrepancies in these results when a comparison is made between the ratio figures on the one hand and Mr. Scudder's incubation test, or the incubation test as judged by smell, on the other (*e.g.*, in the case of Nos. 43 and 159). Hence it would hardly be safe to attempt to draw any conclusion here. Probably the ratio required for safety would be a medium one.

The ratio of oxidised to albuminoid nitrogen (taking the albuminoid = 1) varies between 0·33 and 11·7. Here again no real conclusion can be drawn, but probably a ratio of 3 : 1 would ensure safety against putrescence.

The *chlorine* curve is—relatively speaking—pretty even, showing again the equalisation of the liquid in its passage over and through the soil.

The "*oxygen absorbed*" curve did not vary a great deal, and it will be observed that in these effluents there was a very marked agreement between it and the curve for albuminoid nitrogen.

The average ratio of organic nitrogen to "oxygen absorbed" from permanganate in 4 hours, after allowing for the nitrite present, is, in fourteen effluents, 1 : 5·9. Or, if we omit Nos. 155A and 157, in which the ratios were abnormally high, viz., 1 : 9·9 and 1 : 10·3, the average ratio for twelve effluents is 1 : 5·1 (the extremes being 1 : 3·6 and 1 : 6·6). This latter figure(1 : 5·1) is probably the more correct one.

The average ratio of albuminoid nitrogen to "oxygen absorbed," after allowing for nitrite, is, in fourteen effluents, 1 : 10·1. The figures for this average are remarkably even. Thus, if we leave out Nos. 154, 157, 160 and 169, whose ratios are respectively 1 : 12·4, 1 : 15·5, 1 : 7·8 and 1 : 12·3, the ratios for the remaining ten effluents only vary between 1 : 8·3 and 1 : 10·5, the average for the ten being 1 : 9·3.

If we now revert for a moment to the following Table, which shows some of the results of jointing or incubation upon the nine samples, Nos. 44, 153, 155, 157, 159, 369, 376, 380 and 384, we find that Nos. 153, 376 and 380 were three (of the four out of a total of fifteen) that went bad upon incubation, but that in none of the other six cases was there any very appreciable decrease in nitrate or increase in ammonia (this last observation was only made in Nos. 44, 155 and 159). Speaking broadly, therefore, these six effluents required nothing further to preserve them from putrefaction than the dissolved oxygen* that they already contained—in most cases not very much—and this, of course, ranks them as good.†

---

* Some of the readings for dissolved oxygen must have been too high (*see* Tables of Analysis).

† No. 155, which has been already referred to, is an instance of an effluent just on the border line of safety ; it is rather surprising that it should have kept, or nearly kept, upon incubation.

Table showing some of the results obtained upon Jointing or Incubating several of the Beddington Final and General Effluents.

Number of Samples	44	44 J.	153	153 J.	153 I.	155	155 I.	157	157 I.	159	159 J.	159 I.	369	369 I.	376	376 I.	380	380 I.	384	384 I.
Parts per 100,000.																				
Ammoniacal Nitrogen	2·06	2·14	—		—	1·54	1·66	—	—	1·32	1·15	1·28	—	—	—	—	—	—	—	—
Nitric + Nitrous Nitrogen	0·61	0·76	—		—	0·05	0·02	0·70	0·79	0·12	0·25	0·20	0·24	0·29	—	—	—	—	0·49	0·47
Parts per 1,000, *by volume.*																				
Dissolved oxygen (approx.)	4·8	0·0	—		—	1·3	—	7·6	under 1·0	4·8	under 1·0	trace.	3·0	0·0	—	—	—	—	3·2	0·0
Incubation by smell		+		–			(?)		+		+	+		+		–		–		+

NOTE.—J. = Jointed with mercury and kept at Laboratory temperature for 15 and 36 days.
I. = " " " " incubated at 26·7° C. (80° F.) for varying lengths of time (5 to 35 days).

In conclusion.—Since the surface soil at Beddington is about 15 inches deep and is, moreover, of very good quality for sewage purification, we are to some extent dealing here with a shallow filtration farm. The relative number of particles in unit weight of ignited soil is 46, taking the number at Nottingham as 100, while in unit volume, it is 44; the Beddington soil is thus of a more open texture. But with our present data it is impossible to say how much of the purification effected at Beddington is due to filtration through the top soil and how much to surface irrigation pure and simple. The sewage is practically a domestic one of moderate strength—probably of about average strength. The volume of sewage treated per acre—exclusive of storm water—was very large for a (mainly) surface irrigation farm, being only a little less than at Nottingham and a little more than at Rugby and Aldershot Camp, but the aggregate organic matter treated per acre was less than at Rugby (compare Diagrams 3 and 4). The analytical results of the final and general effluents show that the Beddington farm, used for surface irrigation under the conditions detailed in the Engineering Report, is capable of producing a high-class effluent, chemically speaking, and does so sometimes but not always. Hence one must infer that the land was rather overdosed with sewage at the time the observations were made*. The irregularity caused by the intermittent flushes of storm water sewage in varying quantity no doubt adds much to the difficulty of treatment.

Final and General Effluents.

Percentage Purification, as calculated on the Albuminoid Nitrogen and "Oxygen absorbed" in four hours.

(1) *Albuminoid Nitrogen.*

		Average.
6 chance samples of sewage, screened, and to a small extent settled, yielded	0·99 to 2·36	1·72
7 sets of hourly samples	0·59 to 1·12	0·91
15 final and general effluents	0·06 to 0·23	0·14

Percentage Purification :—

(*a*) Calculated on the chance samples of sewage - 92·1 per cent.
(*b*) ,, ,, hourly ,, ,, - 84·6 ,,

The true percentage probably lies between those two figures.

(2) *Oxygen Absorbed.*

7 chance samples of sewage yielded	7·91 to 18·73	13·70
7 sets of hourly samples	7·85 to 17·45	12·48
15 final and general effluents	0·90 to 2·09	1·41

Percentage Purification :—

(*a*) Calculated on the chance samples of sewage - 89·7 per cent.
(*b*) ,, ,, hourly ,, ,, - 88·7 ,,

Comparison of the total nitrogen in the sewage with that in the final and general effluents.

	Average.
The average total nitrogen in seven sets of hourly samples of sewage was 6·42 to 7·59	7·18
The average total nitrogen in 16 final and general effluents was 1·02 to 3·49	2·20

If we disregard farm subsoil water on the one hand and evaporation on the other, these figures indicate roughly that something like 30 per cent. of the original nitrogen of the Beddington screened sewage finds its way into the brook; but this is almost certainly an over-estimate of the loss, because (1) The hourly sewage samples were probably somewhat weaker than the true average, (2) there is but little subsoil water, and (3) there must have been considerable evaporation from the rye-grass in the month of October.

* Since then some bacterial filters have been erected, with a view to lightening the work laid upon the land.

Experiment to see how much sewage a given area of land would stand.
(Diagrams Nos. 20 and 21.)

At Beddington, as at South Norwood and Leicester, an experiment was made between October 23rd and November 10th, 1900, in order to see how long the purifying power of the soil would hold out under a daily increasing dose of sewage. The details of this experiment are given in Mr. Kershaw's "Additional Notes on Samples"* and in the accompanying diagram. A copy of the latter is appended here, and a few of the main points of Mr. Kershaw's notes may also be repeated.

Two fields were chosen for the experiment, one uncropped arable field of 16 acres area, which was partially underdrained, and one rye-grass field. As the effluents obtained were nearly all *filtration* effluents, it will thus be seen that the conditions were not really analogous to those ordinarily obtaining at Beddington, where the effluents are in the main surface irrigation effluents from cropped land. The arable field had not been sewaged for a fortnight previously, and it was ploughed eight inches deep a few days before the experiment began, Mr. Kershaw noting that the soil seemed to be very clean. The rye-grass field had had a week's previous rest. The sewage was started on to the arable field upon October 23rd, 1900, at the theoretical rate of 25,000 gallons per acre of *total* arable land; that is to say, this would have been the dose had each portion of the ground taken its fair share of sewage from the commencement. But Mr. Kershaw's chart shows how very far this theoretical statement was from the reality, the red line of the chart giving the quantities of sewage treated per acre on the arable land actually irrigated, and the blue line the quantities of 1st field effluent treated on the irrigated rye-grass land. From October 23rd the dose was increased daily by 5,000 gallons (theoretical) per acre until November 7th, at which date 85,000 gallons per acre of arable or 40,000 gallons per acre of joint land were being applied. This is less than the normal amount which is treated at Beddington at one time, viz., 57,000 gallons. On November 7th the dose was suddenly increased to about 126,500 gallons per acre of arable or 56,200 gallons per acre of arable and rye-grass together, and it was continued at this rate for three days, *i.e.*, until November 10th, when the sewage was shut off.

For the first three days no effluent appeared from the second field, the sewage being largely soaked up by the arable land and the remainder by the rye grass. But on October 26th a 2nd field (*filtration*) effluent, No. 163 B, was drawn, and the samples followed one another regularly thereafter.

Mr. Kershaw notes that there was a very small amount of subsoil water under both the arable and rye-grass fields.

1st (Arable) Field Filtration Effluents.

Six samples of these were drawn, two of the six being in duplicate. It was not thought worth while to plot out the figures of their analyses in curves, but a few remarks may be made about them here.

No. 162 (dose 30,000 gallons per acre of arable land theoretically, but 80,000 to 90,000 actually), which was analysed in duplicate, the second time after incubation, was fairly good. The fact of there not being a very great deal of nitrate in it showed that the ground, during its rest, had either not stored up the latter to any great extent, or that the nitrate had been already washed out by rain, or used up by the sewage first run on. This effluent contained a very considerable amount of ferric iron.

No. 163 (dose 35,000 gallons theoretically, but 70,000—80,000 actually) was also analysed in duplicate in the same way. It had a clean smell when drawn, but contained no nitrate, and became putrid upon incubation.

No. 163A (dose 40,000 gallons theoretically, about 70,000 actually) also went putrid when incubated.

No. 163D (dose 50,000 gallons theoretically, about 70,000 actually) was a fairly good sample, and kept sweet upon incubation. This may not improbably have been

* Part IV. Engineering and Practical Report.

due to a heavy rainfall (see diagram). All the above four samples were weak, the result, no doubt, of rain combined with a little subsoil water.

No further sample of 1st field effluent was drawn until No. 169A, on November 6th (dose 85,000 gallons theoretically, about 95,000 actually). As was to be expected, this had a strong sewage smell when drawn, and went very putrid upon incubation.

The limit, therefore, was soon reached on this first field, with the large volumes of sewage actually treated per acre upon it.

2nd Rye-grass Field Filtration Effluents (excepting Nos. 169, 172 and 173, which were partly filtration and partly surface). (*Diagram No.* 21.)

A study of the figures and curves of these analyses shows, among other things, the following points :—

1. The effluents were weak, so far as dissolved organic matter was concerned, but the chlorine curve was not very much lower than the corresponding curve in the Beddington sewages and no lower than that of the ordinary Beddington 3rd field and final effluents; and yet at the time of year when they were drawn—October and November—one would not have expected a very great assimilation of food by the rye-grass rootlets.

2. The seven samples of these filtration effluents, drawn in the month of October, only varied in temperature between the extremely narrow limits of 11·6° and 12·2° C. (53° and 54° F.), while a mixed surface and filtration effluent, also drawn in the same month, went down to 8·3° C. (47° F.).

3. These (filtration) effluents, up to No. 168, drawn on November 5th (dose up to 85,000 gallons theoretically, but 135,000 actually) were in appearance very much like tap water, and with practically no sediment. The last three samples, Nos. 169, 172 and 173, which were partly surface and partly filtration effluents (dose 90,000—130,000 gallons theoretically, but 135,000 actually) were neither so good in appearance nor as regards their analyses. No. 172 may be taken as an illustration of the advisability of having a nitrate factor in an *absolute* standard of purity (assuming, for the moment, such a standard to be in force).

Being percolation effluents, the amounts of dissolved oxygen present, both when drawn and when analysed, were very moderate (all the more as the standard tubes were weakened); there was more oxygen in the last three (surface and filtration) effluents, Nos. 169, 172 and 173, although these were now really deteriorating.

The albuminoid nitrogen and "oxygen absorbed" curves follow one another well, and indeed the curves generally are very consistent.

Mr. Scudder's incubator test and the incubation test as judged by smell agreed in the earlier samples but not in the later ones.*

The determination of organic nitrogen by the method of Kjeldahl *without* reduction was unsatisfactory.

In conclusion.—The soil and subsoil at Beddington are comparable with those at Nottingham and Cambridge, though the Beddington subsoil is much the most stony of the three. The numbers of particles in unit weights of ignited soil and subsoil (Notts. = 100) are :—soil, 46; subsoil, 55. Taking the average depth down to the drains at 6 feet 6 inches, then the relative calculated internal filtration area per unit of surface at Beddington is about four-fifths that at Nottingham. The rate of filtration must also be somewhat similar to the rates at Nottingham and Cambridge, though no doubt appreciably faster. The results obtained in the above short experiment show very clearly (1) the high purifying power of the Beddington soil and subsoil; and (2) the much greater degree of purification that can be effected when such a soil is used for filtration rather than for surface irrigation.

---

* *Note.*—Excepting Nos. 169 and 173, which contained ·04 and ·01 parts of nitrous nitrogen, all the others were free from nitrite when they came to be analysed: and it does not appear to have been tested for in the incubated samples. It is most unlikely, however, that this would have made any difference in the results of Mr. Scudder's test for Nos. 167, 168 and 173,—the only samples which come in question here.

Water from the River Wandle, alone and admixed with effluent (Diagram No. 22).

Referring in his Report to the River Wandle, into which the final effluent from the Beddington farm discharges by two outfalls, Mr. Kershaw says that:—"The general condition of the river appears to be good, and there is evidently no nuisance derived from the mixture of effluent and river water. . . . . The normal ratio of effluent to river water is about 1 : 8, but in wet weather the volume of the river may be relatively much greater, though not much less in dry weather."

Mr. Kershaw's "Additional Notes on Samples" should be read here.*

Nine samples in all were examined completely or partially, the first three being drawn in February, and the last six in October, 1900. Nos. 45, 46 and 47, drawn on Monday, February 26th, 1900, within about an hour's time, are comparable not merely with each other, but also with the final general effluent No. 44.

Taking in the first instance the samples drawn above the effluent outfall, Nos. 45, 150A, 154A and 156A, of which the last three were jointed and incubated before analysis, we find that they were all very well aerated, the last three having maintained their dissolved oxygen excellently after incubation (even allowing for the fact that the standard copper tubes had weakened); and no doubt this would have applied to No. 45 also. This, of course, is satisfactory. No. 45, drawn when the river was slightly above the normal owing to rain, is noted as comparatively colourless but containing an appreciable amount of brownish flocculent matter, with much lime *but practically no sulphate*; and No. 156A, drawn when the river was clear, had also an appreciable quantity of greyish sediment.

Of the samples drawn below the effluent outfall, No. 46 is noted as opalescent and slightly brown, with a small amount of brownish flocculent matter; No. 47 as clear, with some greyish aggregated sediment; and No. 160A as (after incubation) colourless, with a little sediment. When No. 160A was drawn, the river was rather high.

To revert again for an instant to the comparative samples Nos. 44, 45, 46 and 47, the ratio of effluent to river water is given by Mr. Kershaw as being at the time about 1 : 12; but it is quite clear from the appended Curves that, when No. 46 was drawn (130 yards below the effluent outfall), very little mixing had taken place. This sample—No. 46—is virtually the same as the final effluent No. 44, *e.g.*, the quantities of ammoniacal nitrogen and of chlorine are almost equal in both cases, and No. 46 still contained much sulphate in solution. It is difficult to account for the very large quantities of albuminoid and total organic nitrogen found in No. 46, unless some error occurred, either in this analysis or in the analysis of effluent No. 44, of which I am not aware. Of the two, the dissolved oxygen was slightly less in No. 46.

A glance at the curves is sufficient to show that by the time No. 47 was drawn (230 yards lower down than than No. 46) the river was chemically in pretty nearly as good a condition as at the point where No. 45 was taken, that is to say, the dilution had now made itself felt.

With the exception of this single sample, No. 46, therefore, all the others were satisfactory from a chemical point of view, and there was little or no fault on the whole to be found with the river Wandle at Beddington Farm in February and October, 1900, *judged, of course, from the standard of a non-drinking water stream*, although—as stated above—the samples were not altogether free from flocculent matter.

Only one or two further points need be noted here:—

1. The nitrate curve approaches to a straight line.
2. With regard to the few estimations made of organic nitrogen, the Kjeldahl method *without reduction* has given what is probably the better result in the case of No. 47, that sample being too pure for the method *with reduction* to be reliable. In No. 46, on the other hand, the Kjeldahl method without reduction was altogether at fault.

---

* Part IV.: Engineering and Practical Report.

CROYDON (BEDDINGTON) SEWAGE FARM.

TABLES OF ANALYSIS.

INDEX.

	PAGE.
Hourly Sewage Samples, Nos. 443–449	108–109
Sewage and Effluents, Nos. 36, 37, 38, 39	110
„ „ Nos. 39A, 40, 41, 42, 43, 44	111
„ „ Nos. 149, 150, 151	112
„ „ Nos. 152, 153, 154, 155	113
Effluents, Nos. 155A, 156, 157	114
Sewage, Artificial Storm Water, and Effluents, Nos. 158, 159, 160	115
Effluents, Nos. 369, 376	116
„ Nos. 376, 380, 384	117
Special Experiment :—	
Sewage, Artificial Storm Water and Effluents, Nos. 161, 162	118
Effluents, Nos. 163, 163A, 163B, 163C, 163D	119
Sewage, Artificial Storm Water and Effluent, Nos. 164, 164A	120
Effluents, Nos. 165, 166, 167, 167A	121
„ Nos 168, 169, 169A	122
„ Nos. 172, 173	123
River Water above and below Effluent outfall (including one effluent) :—Nos 44, 45, 46, 47	124
„ „ Nos. 150A, 154A, 155B, 156A, 160A, 166A	125

CROYDON (BEDDINGTON) SEWAGE FARM, 1902.

Sets of Hourly Sewage Samples drawn in Equal Quantities per Hour.

No. of Sample	443	444	445
Nature of Sample	Screened Sewage. 24 hours' sample.	Screened Sewage. 24 hours' sample.	Screened Sewage. 24 hours' sample.
Rainfall while sample was being drawn*	0·10″	0·0″	0.0″
Drawn	From Tuesday, 31st December, 1901, 11 a.m., to Wednesday, 1st January, 1902, 10 a.m.	From Wednesday, 1st January, 1902, 11 a.m., to Thursday, 2nd January, 10 a.m.	From Thursday, 2nd January, 1902, 11 a.m., to Friday, 3rd January, 10 a.m.
Analysed	1st January 1902.	2nd January 1902.	3rd January 1902.
Parts per 100,000 *by weight.*			
Ammoniacal nitrogen (by distillation)	4·19	4·18	4·40
Albuminoid "	1·12	0·74	1·00
Nitrous "	0·11	0·10	0·08
Nitric "	0·78	0·85	1·00
Total Nitrogen by Kjeldahl, *with* reduction	7·28	6·78	7·23
Blank	(0·26 in 5·58)	(0·26 in 5·21)	(0·26 in 5·54)
"X" Nitrogen	1·08	0·91	0·75
Organic nitrogen, by Kjeldahl, *with* reduction	2·20	1·65	1·75
Oxygen absorbed from permanganate at 26·7° C. (80° F.), *at once*	3·66	2·81	2·10
" " *after four hours*	17·45	13·59	12·13
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.), *at once*	—	—	—
" " *after four hours*	—	—	—
Smell after incubation	—	—	—
Chlorine	7·90	7.88	8·30
Total solids (gravimetrically)	131·2 {59·6 volatile, 71·6 non-volatile}	115·4 {48·8 volatile, 66·6 non-volatile}	106·8 {45·6 volatile, 61·2 non-volatile}
Solids in suspension	53·0 {30·0 volatile, 23·0 non-volatile}	39·0 {14·8 volatile, 24·2 non-volatile}	21·2 {14·6 volatile, 6·6 non-volatile}
Solids in solution	78·2 {29·6 volatile, 48·6 non-volatile}	76·4 {34·0 volatile, 42·4 non-volatile}	85·6 {31·0 volatile, 54·6 non-volatile}
Cellulose (still containing fat) (by extraction with alkali and acid alone)	12·8	9·20	5·36
Grit	11·24	10·60	2·56
Parts per 100,000 *by volume.*			
Solids by Centrifuge	356·0	215·0	174·0
Remarks	Turbid, with (for a sewage) a small amount of brown sediment. Faint sewage smell. Alkaline.	Turbid, with apparently about the same amount of sediment as No. 443. Slightly sour smell. Alkaline.	Much the same in appearance as the two preceding samples. Odour not offensive. Alkaline.

*Heavy rain fell early in the morning before the first sample was begun.

CROYDON (BEDDINGTON) SEWAGE FARM, 1902.

Sets of Hourly Sewage Samples drawn in Equal Quantities per Hour.

446	447	448	449
SCREENED SEWAGE. 24 hours' sample.	SCREENED SEWAGE. 24 hours' sample.	SCREENED SEWAGE. 24 hours' sample.	SCREENED SEWAGE. 24 hours' sample.
0·14″	0·01″	0·0″	0·0″
From Friday, 3rd January, 1902, 11 a.m., to Saturday, 4th January, 10 a.m.	From Saturday, 4th January 1902, 11 a.m., to Sunday, 5th January, 10 a.m.	From Sunday, 5th January, 1902, 11 a.m., to Monday, 6th January, 10 a.m.	From Monday, 6th January, 1902, 11 a.m., to Tuesday, 7th January, 10 a.m.
6th January 1902	6th January 1902.	7th January 1902.	7th January 1902.
4·61	4·45	5·11	4·53
1·03	0·97	0·59	0·97
None.	0·30	0·12	0·05
0·03	0·36	0·03	0·52
7·52	6·42	7·46	7·59
(0·64 in 6·16)	(0·26 in 4·95)	(0·64 in 6·12)	(0·26 in 11·35)
1·85	0·34	1·61	1·52
2·88	1·31	2·20	2·49
4·81	2·47	1·80	2·98
11·46	10·40	7·85	14·47
——	3·77 } 7 days	3·79 } 6 days	7·73 } 6 days
——	8·21	7·78	13·02
——	Putrid; sulphide.	Strongly putrid; sulphide.	Putrid; blackened.
9·22	7·86	9·02	8·20
106·6 { 43·6 volatile, 63·0 non-volatile	101·8 { 39·0 volatile, 62·8 non-volatile	89·4 { 32·0 volatile, 57·4 non-volatile	112·2 { 53·8 volatile, 58·4 non-volatile
43·0 { 32·6 volatile, 10·4 non-volatile	35·6 { 18·4 volatile, 17·2 non-volatile	21·2 { 16·1 volatile, 5·1 non-volatile	28·4 { 25·0 volatile, 3·4 non-volatile
63·6 { 11·0 volatile, 52·6 non-volatile	66·2 { 20·6 volatile, 45·6 non-volatile	68·2 { 15·9 volatile, 52·3 non-volatile	83·8 { 28·8 volatile, 55·0 non-volatile
7·40	5·80	3·92	7·80
3·04	7·72	1·88	2·40
206·0	173·0	174·0	230·0
Turbid brownish liquid, with a large amount of dark grey sediment. Sewage smell. Alkaline.	Turbid, with a moderate amount of dark brown sediment. Clean smell. Alkaline.	Turbid liquid. Not much sediment (grey in colour) for a sewage. Fishy, but not sewage, smell. Alkaline.	More turbid than the preceding samples, and with a moderate amount of dark brown sediment. Soapy smell. Very strongly alkaline.

CROYDON (BEDDINGTON) SEWAGE FARM, 1900.

Sewage with Effluents.

No. of Sample	No. 36	37	38	39
Nature of Sample	Screened Sewage (passed through Latham's extractors).	First Field Effluent (Field No. 22; rye grass) "heavy snow and frost."	Second Field Effluent over two fields of rye grass.	Third Field or Final Effluent (over three fields, third field pasture).
Drawn	Mon., 12th Feb. 1900, 12.15 noon.	Mon., 12th Feb. 1900, 2.45 p.m.	Mon., 12th Feb. 1900, 4.30 p.m.	Mon. 12th Feb. 1900, 5.15 p.m.
Temperature of sample	9·4° C. (49° F.)	1·1° C. (34° F.)	4·4° C. (40° F.)	2·2° C. (36° F.)
Temperature of air	——	——	——	——
If jointed or incubated	——	——	——	——
Analysed	14th Feb. 1900.	14th Feb. 1900.	15th Feb. 1900.	13th Feb. 1900.
Parts per 100,000, *by weight.*				
Ammoniacal nitrogen: (a) by direct Nesslerization.	Turbid.	Turbid.	Turbid.	Turbid.
(b) by distillation.	8·10	5·73	1·68	*——
Albuminoid nitrogen	2·07	1·32	0·53	——
Nitrous "	0·09	0·07	0·21	0·05
Nitric "	Not done.	None.	1·39	——
Total nitrogen by Kjeldahl, *with* reduction (after nitrite correction).	12·25	9·40	3·94	3·62
Blank	(0·40 in 10·02)	(0·40 in 15·44)	(0·40 in 6·53)	(0·40 in 6·17)
Correction for nitrite	+0·04	+0·03	+0·12	+0·03
"X" nitrogen	1·99	2·28	0·13	——
Organic nitrogen by Kjeldahl, *with* reduction.	4·06	3·60	0·66	——
Organic nitrogen by Kjeldahl, *without* reduction: (a) Taking ammonia by direct Nesslerization.	——	——	——	——
(b) Taking ammonia by distillation	5·41	3·53	0·48	——
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once.*	4·74	2·33	1·10	0·48
" " " *after four hours.*	17·79	10·83	2·81	1·52
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once.*	——	5·33	0·07	0·03 } Six days.
" " " *after four hours.*	——	9·56	1·11	2·53 } Six days.
Smell after incubation	——	Strongly putrid.	Strong mouldy smell.	No smell.
Chlorine	9·44	9·14	7·80	7·06
Gases; parts per 1,000, *by volume.*				
Carbon dioxide (free)	——	38·26	49·37	32·57
Oxygen (boiled out)	——	0·16	0·21	4·41
Nitrogen	——	18·74	20·26	19·20
Remarks	This sample had a copious dark brown sediment. Strong sewage smell. Alkaline.	Brown liquid, containing much putrefactive matter, and with a distinct putrefactive smell. Less alkaline than might have been expected.	Opalescent, with a good deal of bluish-grey flocculent matter aggregated together. Fishy-earthy smell. Distinctly alkaline. Much lime in solution and a good deal of sulphate.	This sample was opalescent to turbidity, and contained a small amount of darkish flocculent matter. Strong fishy-earthy smell. Just alkaline. Much lime in solution and a good deal of sulphate.

*Note.—The other nitrogen figures in this analysis could not be taken, as the standard ammonium chloride was wrong.

CROYDON (BEDDINGTON) SEWAGE FARM, 1900.

Sewage with Effluents.

39a General Effluent.	40 Screened Sewage.	41 First Field Effluent off field No. 22 (rye grass).	42 Second Field Effluent off field No. 28 (rye grass).	43 Final (Third Field) Effluent off field No. 45 (pasture).	44 General Final Effluent.	44 Large Duplicate.
Thurs. 15th Feb. 1900, 12.30 noon. 1·1° C. (34° F.)	Tues., 20th Feb. 1900, 11.45 a.m. 10·0° C. (50° F.)	Tues., 20th Feb. 1900, 1.15 p.m. 8·3° C. (47° F.)	Tues., 20th Feb. 1900, 2.50 p.m. 7·8° C. (46° F.)	Tues., 20th Feb. 1900, 4 p.m. 7·2° C. (45° F.)	Mon., 26th Feb. 1900, 4.35 p.m. 13·3 C. (56° F.)	——
——	——	——	——	——	——	——
——	——	——	——	——	——	Jointed 27th Feb.
16th Feb. 1900.	21st Feb. 1900.	21st Feb. 1900.	22nd Feb. 1900.	23rd Feb. 1900.	27th Feb. 1900.	14th March 1900.
Turbid.	Turbid.	About 1·44	——	Turbid.	1·73 approx.	2·12
(Feb. 17) 1·29 (Feb. 16) 1·19	4·15	1·56	1·14	0·93	2·06	2·14
0·22 0·23	1·33	0·39	0·23	0·15	0·23	0·15
0·03	0·08	0·06	0·06	0·04	0·07	0·07
0·60	Not done (should have been).	1·68	1·14	1·39	0·54	0·69
2·33	9·86	4·20	2·97	2·56	2·97	2·93
(0·40 in 4·10)	(0·40 in 16·17)	(0·40 in 7·10)	(0·40 in 5·12)	(0·40 in 4·48)	(0·40 in 5·10)	(0·22 in 4·41)
+0·02	+0·04	+0·03	+0·03	+0·02	+0·04	+0·04
0·19	4·30 (Too high if any nitrate was present)	0·51	0·40	0·05	0·07	None. (—0·12)
0·41	5·63	0·90	0·63	0·22	0·30	0·15
——	——	About 1·14	——	——	0·39 approx.	——
0·43	4·96	1·02	0·31	0·39	0·06	——
0·32 } Feb. 16th.	3·09	0·82	0·59	0·32	0·80	0·24
2·09 } Feb. 16th.	17·00	3·25	1·61	1·40	2·06	1·36
——	——	0·62	0·58	0·77	6 Days. 0·43 / 2 Days. 0·54	——
——	——	1·89	1·17	1·53	1·47 / 1·59	——
——	——	Mouldy (not earthy).	Not noted.	Putrid, sewage smell.	Strong earthy.	——
——	9·94	6·28	5·66	5·08	6·46	——
——	——	30·42	20·88	21·05	29·36	34·69
——	——	1·33	4·67	3·59	4·76	0·02
——	——	16·81	15·91	16·17	14·54	14·92
This sample contained a large amount of storm (snow?) water. It was very turbid, and with a considerable amount of suspended matter. Earthy smell. Alkaline.	Considerable light brown and grey deposit. The sewage odour was not very strong.	Turbid, with an appreciable amount of dark floating flocculent matter in somewhat large particles. Fishy smell. Very slightly alkaline. A great deal of lime and much sulphate in solution. This is very fair for a single field effluent.	Only very slightly opalescent and containing almost no flocculent matter. No smell. Very distinctly alkaline. Much lime and a good deal of sulphate in solution.	This looked an excellent effluent, clear, and with only comparatively few greyish, flocculent particles. Distinctly alkaline. A great deal of lime and much sulphate in solution.	Distinctly brownish and turbid, with an appreciable amount of flocculent matter. Fishy-earthy smell. Very alkaline.	One or two tenths of a c.c. of gas in neck of bottle, but no pressure. Clean, fishy - earthy smell.

Note.—It is curious that this effluent should not have kept.
In Nos. 42 and 43 it looks as if the determination of the organic nitrogen by the method of Kjeldahl, without reduction, was the more correct.

CROYDON (BEDDINGTON) SEWAGE FARM, 1900.

Sewage with Effluents.

No. of Sample	149	150	151	151	151
Nature of Sample	Screened and Settled Sewage.	First Field Effluent (over rye-grass).	Second Field Effluent (from permanent pasture).	Large Duplicate.	Small Duplicate.
Drawn	Wed., 3rd Oct. 1900, 11.45 a.m.	Wed., 3rd Oct. 1900, 2·0 p.m.	Wed., 3rd Oct. 1900, 3.30 p.m.	—	—
Temperature of sample	15·0° C. (59° F.)	10·6° C. (51° F.)	12·8° C. (55° F.)	—	—
Temperature of air	12·8° C. (55° F.)	16·1° C. (61° F.)	13·9° C. (57° F.)	—	—
If jointed or incubated	—	—	—	Jointed 4th Oct. Apparently opened and re-jointed 24th October.	Jointed and incubated 4th October.
Analysed	4th Oct. 1900.	4th Oct. 1900.	5th Oct. 1900.	Opened 14th Nov. 1900.	Opened 13th Oct. 1900.
Parts per 100,000 *by weight.*					
Ammoniacal nitrogen :					
(a) By direct Nesslerization	—	—	—	—	—
(b) By distillation	8·56	3·42	1·68	—	—
Albuminoid nitrogen	1·49	0·47	0·19	—	—
Nitrous "	Mere trace.	Trace.	Trace.	—	—
Nitric "	Not done.	0·14	Not appreciable.	—	—
Total nitrogen by Kjeldahl, *with* reduction (after nitrite correction).	11·70	5·14	2·46	—	—
Blank	(0·17 in 8·34)	(0·17 in 7·37)	(0·17 in 4·48)	—	—
Correction for nitrite	None.	None.	None.	—	—
"X" Nitrogen	1·65	1·11	0·59	—	—
Organic nitrogen by Kjeldahl, *with* reduction.	3·14	1·58	0·78	—	—
Organic nitrogen by Kjeldahl, *without* reduction :					
(a) Taking ammonia by direct Nesslerization.	—	—	—	—	—
(b) Taking ammonia by distillation.	—	—	1·21	—	—
Oxygen absorbed from permanganate at 26·7° C. (80° F.) ; *at once.*	7·04 (Oct. 5th. Estimation on Oct. 4th lost.)	1·97	1·01	—	—
" " " *after four hours.*	15·22	5·81	2·71	—	—
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.) ; *at once.*	—	—	1·42	—	—
" " " *after four hours*	—	—	2·81	—	—
Smell after incubation	—	—	Strong peppermint, which masked other smell (if any).	—	—
Chlorine	?	7·40	7·00	—	—
Gases ; Parts per 1,000, *by volume.*					
Carbon dioxide (free)	—	—	—	—	—
Oxygen (boiled out)	—	—	—	—	—
Oxygen (by cuprous chloride) :					
(a) When drawn	—	Less than 1·0	—	—	—
(b) " analysed	—	—	Trace only.	—	—
Nitrogen	—	—	—	—	—
Remarks	This sample was yellow, with much dark grey solid matter in it. Sewage and very strong peppermint smell. Alkaline.	Turbid, slightly yellow liquid, with practically no sediment, but what looked like very finely divided grey matter in suspension. Strong smell of peppermint and also of sewage. Alkaline.	Opalescent and of a rather pale yellow-brown colour. Very little sediment (what there was had a darkish tint). Still a distinct smell of peppermint.	This sample now had a large black deposit and a foul smell, though the peppermint odour was still observable also. Not analysed.	Again a black sediment. The liquid still smelt strongly of peppermint, but also of sulphuretted hydrogen. Not analysed.

CROYDON (BEDDINGTON) SEWAGE FARM, 1900.

Sewage with Effluents.

152	153	153	153	154	155	155
Screened and Settled Sewage.	Final Effluent, same source as No. 151 (over two Fields). Very warm weather.	Small Duplicate.	Large Duplicate.	Final Effluent (over three Fields).	Final Effluent (over three Fields).	Small Duplicate.
Mon., 8th Oct. 1900, 11.0 a.m.	Mon., 8th Oct. 1900, 2.30 p.m.	—	—	Tues., 9th Oct. 1900, 2.0 p.m.	Wed., 10th Oct. 1900, 1.45 p.m.	—
14·4° C. (58° F.)	15·0° C. (59° F.)	—	—	16·7° C. (62° F.)	14·4° C. (58° F.)	—
18·3° C. (65° F.)	20·6° C. (69° F.)	—	—	18·3° C. (65° F.)	14·4° C. (58° F.)	—
—	—	Jointed and incubated 9th October.	Jointed 9th October.	—	—	Jointed 11th Oct. Incubated 13th October.
9th Oct. 1900.	9th Oct. 1900.	Opened 18th Oct. 1900.	Opened 14th Nov. 1900.	10th Oct. 1900.	11th Oct. 1900.	22nd Oct. 1900.
—	—	—	—	1·08	—	—
8·09	3·10	—	—	0·89	1·54	1·66
2·10	0·21	—	—	0·11	0·13	0·13
Trace.	Trace.	—	—	0·05	0·03	Trace
Not done.	0·07	—	—	0·07	0·02	0·02
12·00	3·49	—	—	1·35	1·70	—
(0·17 in 8·58)	(0·17 in 6·29)	—	—	(0·17 in 2·48)	(0·17 in 3·11)	—
None.	None.	—	—	+0·03	+0·02	—
1·81	0·11	—	—	0·23	None (— 0·02)	—
3·91	0·33	—	—	0·34	0·13	—
—	—	—	—	0·09	—	—
—	0·32	—	—	0·28	0·09	—
9·02	0·70	—	—	0·45	0·37	0·42
18·73	1·79	—	—	1·42	1·32	—
—	0·74	—	—	0·57	0·50	—
—	1·80 (5½ hours)	—	—	1·35 (5⅔ hours)	1·44	—
—	Putrid.	—	—	Slight smell like mustard; not exactly putrid.	Nothing wrong; Earthy; Not quite sweet (Three observers.)	Not quite sweet.
7·60	7·80	—	—	8·20	7·80	—
—	—	—	—	—	38·56	—
—	—	—	—	—	1·28	—
—	About 1·0	—	—	3·5	—	—
—	Practically none.	—	—	1·0 to 1·5 (Very green to read).	About 1·0 (Three observers).	—
—	—	—	—	—	14·90	—
Turbid yellow liquid, with a large amount of dark-coloured solid matter. Strong smell of sewage and of peppermint. Alkaline.	Nearly clear, with a slight brown tint (greenish when drawn). Very little flocculent matter, which was more grey than brown. Distinct sewage smell when drawn. Clean, or possibly faint sewage smell, on October 9th. Alkaline. *Note.*—This land had had barely three days' rest.	After incubation this sample was putrid, though not badly putrid. This is a good instance of a sample not very far over the border line.	The somewhat small deposit was black, and the liquid putrid, though not excessively so. Not analysed.	Liquid nearly clear, with a slight but distinct brown tint. Mere trace of grey-brown flocculent matter. Good clean smell. Alkaline. This is a border line sample.	This sample looked fairly good, though not so good as No. 154. It was clear and slightly yellow, with hardly any sediment, which was brownish. Clean smell. Moderately alkaline. A great deal of lime in solution, a moderate amount of sulphate, and more than a trace of iron (mostly or entirely ferric).	This, again, is an interesting border line effluent.

CROYDON (BEDDINGTON) SEWAGE FARM, 1900.

Effluents.

No. of Sample	155a		156		157	157
Nature of Sample	Final Effluent (over three fields).		Final Effluent (over two fields).		Final Effluent (over three fields).	Small Duplicate.
Drawn	Thursday, 11th October 1900, 1.15 p.m.		Monday, 15th October 1900, 2.45 p.m.		Tuesday, 16th October 1900, 12·45 noon.	——
Temperature of sample	13·3° C. (56° F.)		10·0° C. (50° F.)		10·0° C. (50° F.)	——
Temperature of air	11·1° C. (52° F.)		10·0° C. (50° F.)		10·6° C. (51° F.)	——
If jointed or incubated	——		——		——	Jointed and incubated 17th October.
Analysed	12th October 1900.		16th October 1900.		17th October 1900.	22nd October 1900.
Ammoniacal nitrogen—	(B)	(A)	(B)	(A)		
(a) by direct Nesslerization	——		——		0·32	——
(b) by distillation	0·28	——	Retort. 2·26	Flask. 2·45 2·41	0·23	——
Albuminoid nitrogen	0·14	——	0·14	——	0·06	——
						Distillation. Oxalate.
Nitrous "	0·04	0·04	0·05	——	0·04	0·81 0·77
Nitric "	0·54	0·54	0·14	——	0·66	
	without sugar					
Total nitrogen by Kjeldahl, *with* reduction (after making nitrite correction).	1·07	0·85	2·72	——	1·02	——
Blank	(0·17 in 1·66; 0·13 in 1·46)		(0·17 in 3·94)		(0·17 in 1·57)	——
Correction for nitrite	+0·02	+0·02	+0·03	——	+0·02	——
"X" nitrogen	0·07	——	0·13	——	0·03	——
Organic nitrogen by Kjeldahl, *with* reduction.	0·21	——	0·27	——	0·09	——
Organic nitrogen by Kjeldahl, *without* reduction: Taking ammonia by distillation	——	0·14	——	——	0·07	——
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once*	0·43	——	0·43	——	0·35	——
" " " *after four hours*	1·28	——	1·42	——	0·98	——
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once*	0·57	——	0·30	——	0·37	——
" " " *after four hours*	1·10	——	0·74	——	0·98	——
Smell after incubation	Clean, earthy.		Putrid.		Clean, earthy.	Clean, fishy-earthy.
Chlorine	8·0	——	5·80	——	——	——
Gases: parts per 1,000, *by volume.*						
Carbon dioxide (free)	——	——	27·46	——	29·79	——
Oxygen (boiled out)	——	——	†7·32	——	7·64*	——
" (by cuprous chloride)—						
(a) When sample was drawn	Over 6·0		4·5	——	——	——
(b) " " " analysed	Over 6·0 (probably 7·0) on 12th.		†Abt. 4·0, 3·75, 4·0 (three observers).		6·75, 5·75, 5·50 (three observers).	Less than 1·0
Nitrogen	——	——	16·04	——	15·24	——
Remarks	This was an excellent looking effluent, with only a very faint brown tint. Practically no sediment. Clear. Sweet smell.		Faintly opalescent, but almost entirely free from flocculent matter. Good, clean smell. This is a contradictory analysis. †Cannot explain this discrepancy in the figures for oxygen.		This looked a beautiful effluent, clear, and with a mere trace of darkish, flocculent matter (very likely grit). Sweet smell. * This is a remarkable figure. It almost represents saturation at the temperature at which the effluent was drawn (10·6° C.). I am not aware of any error; the nitrogen works out almost right for the temperature (14·6° C.).	Very good effluent.

CROYDON (BEDDINGTON) SEWAGE FARM, 1900.

Sewage with Effluents.

158 Screened Sewage (after slight rain).	159 Final Effluent (over three fields).	159 Small Duplicate.	159 Large Duplicate.	160 Final Effluent (over three fields).	158 Artificial Storm Water,
Wednesday, 17th October 1900, 12.0 noon.	Wednesday, 17th October 1900, 5 p.m.	—	—	Thursday, 18th October 1900, 2.30 p.m.	—
15·6° C. (60° F.)	12·2° C. (54° F.)	—	—	12·2° C. (54° F.)	—
17·8° C. (64° F.)	13·3° C. (56° F.)	—	—	14·4° C. (58° F.)	—
—	—	Jointed and incubated, 18th October	Jointed, 18th October.	—	—
18th October 1900	18th October 1900	29th October 1900	20th November 1900.	19th October 1900.	—
—	—	—	—	—	Made by diluting Beddington Sewage, No. 158, down to the Mersey and Irwell standard of albuminoid ammonia (0·1 grain per gallon). Took 20 c.c. sewage and 380·6 tap water on Friday, 19th October.
9·71	1·32	1·28	1·15	1·61	
2·36*	0·13	0·13	0·10	0·16	
None.	0·04	0·25	0·04	0·03	
Not done.	0·08		0·16	0·05	
13·42 (no sugar).	1·70	—	Sugar. 1·88† No sugar. 1·54†	1·98	
(0·13 in 9·71)	(0·17 in 2·52)	—	(0·12 in 2·78). (0·12 in 2·29).	(0·17 in 2·91)	Incubated two portions :— (a) At atmospheric temperature ; (b) At 26·7° C. (80° F.) for about eight days, and then determined the "oxygen absorbed" from permanganate.
None.	+0·02	—	+0·02	+0·02	
1·35	0·13	—	0·45 0·11	0·14	
3·71	0·26	—	0·55 0·21	0·30	
—	—	—	—	0·14	Before incubation, Oct. 19. After incubation, abt. Oct. 27. (a) (b)
2·44†	0·43	—	0·27	0·41	
11·00†	1·13	—	1·28	1·28	(?) 0·20 0·37 0·50
—	0·41	—	0·33 Six days.	0·55	Both of these incubated samples had a *strong putrid odour*.
—	1·27	—	1·25	1·23	
—	Sweet, earthy.	—	Sweet.	Suspicious ; Clean (Two observers).	
10·50	7·80	—	—	8·60	
—	—	—	—	—	
—	—	—	—	—	
—	—	—	—	(?) 2·0	
—	4·75, 4·80, 5·20 (three observers). Green-blue, not easy to read.	Trace.	Under 1 c.c. (difficult to read).	6·2, 5·5, 5·25‡ (three observers).	
—	—	—	—	—	
This sewage contained a moderate amount of light brown sediment. Strong sewage smell. Alkaline.	This looked a good sample, but not so good as No. 157. Nearly clear, with a distinct brownish tinge. Very little solids in suspension. What there was, was red-brown and black (the latter probably earth).	Smell clean, but rather strong fishy-earthy.	Lemon-coloured and clear, with but a small deposit of brown flocculent matter. Clean smell. A small bubble of gas at top of bottle.	This looked a good effluent, clear, and with practically no sediment. It had, however, a distinct yellow tint. Clean though peculiar smell.	

* About this time the distilled water yielded some "albuminoid" ammonia.
† These figures are probably too low, especially the first.

† Bad agreement.

‡ The blue colour of the copper standard tubes was weakening.

CROYDON (BEDDINGTON) SEWAGE FARM, 1901.

Effluents.

No. of Sample	369	369	376
Nature of Sample	General Effluent.	Small Duplicate.	General Effluent.
Drawn	Monday, 7th October 1901, 12 noon.	—	Tuesday, 8th October 1901, 12·30 noon.
Temperature of sample	10·0° C. (50° F.)	—	11·7° C. (53° F.)
Temperature of air	10·0° C. (50° F.)	—	13·3° C. (56° F.)
If jointed or incubated	—	Jointed and incubated, 8th October.	—
Analysed	8th October 1901.	9th November 1901.	9th October 1901.
Parts per 100,000 *by weight.*			
Ammoniacal nitrogen	1·39	—	1·82
Albuminoid nitrogen	0·07	—	0·15
Nitrous "	0·04	0·29 Containing about 0·04 nitrite nitrogen.	0·02
Nitric "	0·20		0·22
Total nitrogen by Kjeldahl, *with* reduction (no correction for nitrite).	1·79	—	2·31
Blank	(0·30 in 2·91)	—	(0·30 in 3·67)
"X" Nitrogen	0·09	—	0·10
Organic nitrogen by Kjeldahl, *with* reduction.	0·16	—	0·25
Oxygen absorbed from permanganate at 26·7° C. (80° F); *at once.*	0·31	—	0·30
" " " *after four hours.*	0·91	—	1·56
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once.*	0·37	—	0·23
" " " *after four hours.*	1·06	—	1·27
Smell after incubation	Sweet; about 0·03 nitrite nitrogen.	—	Sweet; No nitrite.
Chlorine	8·26	—	7·56
Parts per 100,000 *by volume.*			
Solids by centrifuge	6·0 approx. Really a mere trace.	—	27·0
Gases; Parts per 1,000 *by volume.*			
Oxygen (by cuprous chloride) when sample was analysed	3·0	None.	1·2
Remarks	This sample was clear, but with a yellow tinge. It contained a minute quantity of sediment. No smell. Alkaline.	No notes were made, but the effluent obviously kept well.	This sample was fairly clear and had no smell when drawn. On October 9th it was yellow coloured, with a moderate amount of light brown sediment. No smell. Alkaline. This is a border-line sample.

CROYDON (BEDDINGTON) SEWAGE FARM, 1901.

Effluents.

376 SMALL DUPLICATE.	380 GENERAL EFFLUENT (rather cloudy when drawn).	380 SMALL DUPLICATE.	384 GENERAL EFFLUENT. (clearer than the previous day's sample).	384 SMALL DUPLICATE.
—	Wednesday, 9th October 1901, 12 noon.	—	Thursday, 10th October 1901, 12 noon.	
—	13·3° C. (56° F.)	—	13·3° C. (56° F.)	
—	11·1° C. (52° F.)	—	11·7° C. (53° F.)	
Jointed and incubated, 9th October.	—	Jointed and incubated, 10th October.		Jointed and incubated, 11th October.
Opened 5th November 1901.	10th October 1901.	Opened 14th November 1901.	11th October 1901.	5th November 1901.
—	2·25	—	1·16	
—	0·19	—	0·08	
—	None.	—	0·04	0·47 Containing about 0·04 nitrite nitrogen.
—	0·03	—	0·45	
—	(a) 2·83 (b) 2·78 about 18th.	—	1·76	—
—	(0·34 in 4·49 and in 4·42.)	—	(0·30 in 2·87)	—
—	0·36 (a)	—	0·03	—
—	0·55 (a)	—	0·11	—
—	0·41	—	0·12	—
—	2·00	—	Lost	—
—	0·72	—	0·28	—
—	2·07	—	1·04	—
—	Putrid; smell of sulphuretted hydrogen.	—	Sweet; trace of nitrite	—
—	8·22	—	8·66	—
—	72·0	—	4·0	—
—	None.	—	3·2	None.
When opened, this was putrid and blackened, and smelt of sulphuretted hydrogen. Not analysed.	This was a rather turbid, colourless liquid, with apparently no precipitated sediment. Fishy smell. Alkaline.	When opened, the supernatant liquid was clear and fairly colourless; the sediment, of which there was a good deal, was black. Putrid, and smelling of sulphide. Alkaline. Not analysed.	This sample had a slight yellow tint and contained a very small amount of light brown sediment. No smell. Alkaline.	Slight yellow tinge, with a small amount of brown sediment.
Note.—This is another instance of incubation not being completed at the end of five days.			*Note.*—It will be observed that in the duplicate samples, Nos. 369 and 384, the oxygen is used up while the nitrate remains practically unaltered.	

CROYDON (BEDDINGTON) SEWAGE FARM, 1900.

Special Experiment.

No. of Sample	161	162	162	161
Nature of Sample	Screened Sewage.	Filtration Effluent from Arable Land.	Small Duplicate.	Artificial Storm Water.
Drawn	Wednesday, 24th Oct. 1900, 12.15 noon.	Wednesday, 24th Oct. 1900, 2.30 p.m.	—	—
Temperature of sample	14·4° C. (58° F.)	13·9° C. (57° F.)	—	—
Temperature of air	15·0° C. (59° F.)	15·6° C. (60° F.)	—	—
If jointed or incubated	—	—	Jointed 25th Oct.; outside incubator till 27th Oct., inside till 9th Nov.	—
Analysed	25th Oct. 1900.	25th Oct., 1900.	9th Nov. 1900.	—
Parts per 100,000 *by weight.*				
Ammoniacal nitrogen—				
(a) By direct Nesslerization	*—	0·82	—	Sample No. 161 diluted to a storm water of the Mersey & Irwell standard of albuminoid nitrogen (on 1·60), *i.e.*, 25 c.c. sewage and 313 c.c. tap water, 25th Oct. 1900. (a) was kept in full bottle at atmospheric temperature; (b) was incubated at 26·7° C. (80° F.) till Nov. 5th. The "oxygen absorbed" was then re-determined.
(b) By Distillation	—	0·79	0·72	
Albuminoid nitrogen	—	0·15	0·07	
Nitrous "	None.	0·02	None.	
Nitric "	Not done.	0·93 (approximate)	0·29	
Total nitrogen by Kjeldahl, *with* reduction (after making nitrite correction).	6·82 (with sugar).	(a) 1·70 (b) 1·62	—	
Blank	—	(0·17 in 2·53) (0·13 in 2·39)	—	
Correction for nitrite	—	+ ·01	—	
"X" nitrogen	—	?	—	
Organic nitrogen by Kjeldahl, *with* reduction.	—	?	—	
Organic nitrogen by Kjeldahl, *without* reduction:				
(a) Taking ammonia by direct Nesslerization.	—	—	—	Oct. 25. Nov. 5.
(b) Taking ammonia by distillation.	—	—	—	—
Oxygen absorbed from permanganate at 26·7° C. (80° F.), *at once.*	2·26	0·16	0·05	(a) (b) 0·13 0·09 0·23 Both (a) and (b) were putrid.
" " *after four hours*	7·91	0·89	—	
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.), *at once.*	—	0·25	—	—
" " *after four hours*	—	0·91	—	—
Smell after incubation	—	A little like mustard. Not quite sweet.	Slight smell like mustard.	—
Chlorine	5·7	7·1	—	—
Gases: parts per 1,000, *by volume.*				
Oxygen (by cuprous chloride):				
(a) When sample was drawn	—	Less than 1·0.	—	—
(b) When sample was analysed	—	None, or merest trace.	—	—
Remarks	When this sample was drawn, some soapy matter was coming down. It contained only a little sediment. Alkaline. **Note.*—The figures for the nitrogen in this sample are not given, as the distilled water used was not reliable, yielding as it did some "albuminoid" ammonia.	This sample was dim, but with only a very little brown suspended matter. Fishy-earthy or mustard smell. Slightly alkaline. Much lime, but not a very great deal of sulphate in solution; a very considerable amount of ferric iron. This large amount of iron is striking. *This effluent is entirely the result of filtration.*	After incubation this was a practically colourless clear liquid, with a considerable amount of light brown flocculent matter. Alkaline	—

CROYDON (BEDDINGTON) SEWAGE FARM, 1900.

Special Experiment.

163 — Filtration Effluent from same source as No. 162.	163 — Small Duplicate.	163a — Filtration Effluent from arable land.	163b — Final Filtration Effluent (*i.e.* first through arable, then through rye-grass field).	163c — Final Filtration Effluent.	163c — Small Duplicate.	163d — Small Sample Arable Field Effluent.
Thursday, 25th Oct. 1900, 12.30 noon.	—	Friday, 26th Oct. 1900, 12.15 noon.	Friday, 26th Oct. 1900, 12.45 noon.	Saturday, 27th Oct. 1900, 12.45 noon.	—	Monday, 29th Oct. 1900, 12.0 noon.
13·3° C. (56° F.)	—	13·9° C. (57° F.)	11·7° C. (53° F.)	12·2° C. (54° F.)	—	13·3° C. (56° F.)
13·3° C. (56° F.)	—	7·2° C. (45° F.)	7·2° C. (45° F.)	10·6° C. (51° F.)	—	12·8° C. (55° F.)
—	Jointed and inside incubator 26th Oct. (on top part of time).	Jointed and incubated 27th Oct.	—	—	Jointed and incubated 29th Oct.	—
—	5th Nov. 1900.	Opened 12th Nov. 1900.	27th Oct. 1900.	29th Oct, 1900.	26th Nov. 1900.	—
—	—	—	—	0·02 approximate	—	—
0·90	—	—	0·07	0·02	—	1·52
0·19	—	—	0·035	0·02	—	0·15
None.	—	—	None, or mere trace.	None.	0·43	0·16
None.	—	—	0·44	0·43		
1·05	—	—	0·57	0·65	—	—
(0·17 in 1·65)	—	—	(0·13 in 0·97)	(0·17 in 1·08)	—	—
None.	—	—	None.	None.	—	—
None. (— 0·04)	—	—	0·025	0·18 (?)	—	—
0·19	—	—	0·06	0·20 (?)	—	—
—	—	—	—	0·06	—	—
—	—	—	—	0·06	—	—
0·42	0·39	—	0·07	0·21	—	0·15
1·39	—	—	—	0·52	—	—
0·72	—	—	0·04	0·07 (7 days)	—	—
1·61	—	—	0·30	0·50 (7 days)	—	—
Strong smell of sulphuretted hydrogen. Putrid.	Putrid.	—	Sweet and clean.	Quite sweet.	—	Clean smell.
7·0	—	—	7·26	7·10	—	—
Less than 1·0	—	—	—	2·0	—	—
Less than 1·0	—	—	2·5, 2·8, 2·8, (three observers; the standards seem to have got paler).	2·5, 2·8, (two observers).	Mere trace.	Sample too small.
This sample looked exactly like No. 162, but the small amount of flocculent matter present was not so red. Clean fishy - earthy smell.	When opened this was very putrid and smelling of ammonium sulphide.	When opened this was strongly putrid, with black deposit.	This looked a beautifully clear effluent like drinking water, with only the merest trace of pale brown flocculent matter.	Beautiful clear effluent, with only the merest trace of suspended matter. Very slight clean, earthy smell.	Clear, with a little brown flocculent matter. The only change which this effluent has undergone is to lose its 2·5 c.c. of oxygen.	When opened after incubation, this sample was brownish with some grey-brown sediment. Quite sweet. This is evidently just within the border line.

CROYDON (BEDDINGTON) SEWAGE FARM, 1900.

Special Experiment—*continued.*

No. of Sample	164	164a	164a	164a
Nature of Sample	Final Filtration Effluent.	Screened Sewage.	164a Diluted to Storm Water of M. & I. Albuminoid nitrogen Standard.	164a Diluted To Storm Water of *half* the M. & I. Albuminoid nitrogen Standard.
Drawn	Monday, 29th October 1900 12.45 noon.	Wednesday, 31st October 1900 11.30 a.m.	—	—
Temperature of sample	11·7° C. (53° F.)	14·4° C. (58° F.)	—	—
Temperature of air	12·2° C. (54° F.)	18·3° C. (65° F.)	—	—
If jointed or incubated	—	—	—	—
Analysed	30th October 1900	1st November 1900	—	—
Parts per 100,000 *by weight.*			1st November 1900. 100 c.c. Sewage, 737 c.c. Tap Water. Incubated till 8th November.	1st November 1900. 50 c.c. Sewage, 737c.c. Tap Water. Incubated till 8th November.
Ammoniacal nitrogen—				
(a) by direct Nesslerization	0·03	—	(a) At atmospheric temperature.	(a) At atmospheric temperature.
(b) by distillation	0·03	5·44	(b) At 26·7° C. (80° F.)	(b) At 26·7° C. (80° F.)
Albuminoid nitrogen	0·03	0·99		
Nitrous ,,	None.	None.	The "oxygen absorbed" was determined as before.	The "oxygen absorbed" was again determined.
Nitric ,,	0·59	Not done.	—	—
Total nitrogen by Kjeldahl, *with* reduction (after making nitrite correction)	0·67	7·47	—	—
Blank	(0·17 in 1·10)	(0·12 in 5·45)	—	—
Correction for nitrite	None.	None.	—	—
"X" nitrogen	0·02	1·04	—	—
Organic nitrogen by Kjeldahl, *with* reduction.	0·05	2·03	—	—
Organic nitrogen by Kjeldahl, *without* reduction: (a) Taking ammonia by direct Nesslerization.	0·04 (This stood a long time.)	—	—	—
(b) Taking ammonia by distillation	—	—	1st Nov. Before incubatn. 0·23 / 8th Nov. After incubatn. (a) 0·26 (b) 0·43	1st Nov. Before incubatn. 0·14 / 8th Nov. After incubatn. (a) 0·14 (b) 0·17
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once.*	0·27	1·76		
,, ,, ,, *after four hours.*	0·54	8·27	(a) Was putrid after incubation, and (b) very putrid.	After incubation (a) was putrid and (b) either sweet or doubtful (three observers).
Oxygen absorbed from permanganate in sample incubated for five days at 26·7° C. (80° F.); *at once*	0·27 } 6 days.	—	—	—
,, ,, ,, *after four hours.*	0·41 } 6 days.	—	—	—
Smell after incubation	Sweet.	—	—	—
Chlorine	7·3	7·7	—	—
Gases; Parts per 1,000 *by volume.*				
Oxygen (by cuprous chloride): (a) When sample was drawn	2·25	—	—	—
(b) ,, ,, ,, analysed	3·7 / 3·3 Two observers. Standards weakening.	—	—	—
Remarks	This looked a beautiful effluent, just like a tap water. Practically no suspended matter.	Very small amount of light brown sediment Sewage smell. Alkaline.		

CROYDON (BEDDINGTON) SEWAGE FARM, 1900.

Special Experiment—*continued.*

165 Final Filtration Effluent.	165 Small Duplicate.	166 Final Filtration Effluent.	167 Final Filtration Effluent from Rye Grass.	167a (Small Sample) Arable Field Effluent.
Wednesday, 31st October 1900. 1·0 p.m. 11·7° C. (53° F.)	——	Friday, 2nd November 1900. 12.40 noon. 12·2° C. (54° F.)	Saturday, 3rd November 1900. 12.30 noon. 12·2 (54° F.)	Saturday, 3rd November 1900. 12.20 noon. 13·3 (56° F.)
18·9° C. (66° F.)	——	14·4° C. (58° F.)	14·4 (58° F.)	14·4 (58° F.)
——	Jointed and put on top of Incubator 1st Nov. Inside 10th Nov.	——	——	Jointed and put on top of Incubator 5th Nov. Inside 10th Nov. Opened
1st November 1900.	15th November 1900.	3rd November 1900.	5th November 1900.	15th November 1900.
0·09	——	——	0·24	——
0·08	——	0·16	0·20	——
0·04	——	0·05	0·03	——
None.	By distillation 0·56	None.	None.	——
0·52	——	0·43 (*Oxalate 0·39 approx.)	0·41	——
0·71 (0·17 in 1·17)	—— ——	0·76 (0·17 in 1·23)	0·63 (0·17 in 1·06)	—— ——
None.	——	None.	None.	——
0·07	——	0·12	None (−0·01)	——
0·11	——	0·17	0·03	——
0·03 (Stood a long time)	——	——	——	——
——	——	None. (Stood for three weeks)	None. (Stood for three weeks)	——
0·25	——	0.27	0·12	——
0·54	——	——	0·68	——
				——
0·10 0·53	—— ——	0·14 0·54	0·29 0·78 } 7 days.	——
No smell.	Clean, fishy-earthy.	Sweet.	Doubtful; tainted. (Two observers.)	——
——	——	7·22	7·22	——
2·00	——	——	about 1·75	——
2·25 2·50 2·80 } Three observers Standards weakening.	about 1·0 1·5 } Two observers	1·50 } Two observers.	less than 0·50 about 0·30 } Two observers. (Standards weakened)	——
This was another beautiful looking effluent, just like tap water. No appreciable sediment.		Another excellent looking effluent. A little light-brown sediment. * This Nitrate estimation (using oxalate) is approximate, because the blank gave a turbidity with the Nessler Reagent, while the estimation proper did not.	Another beautiful looking effluent, containing a mere trace of grey-brown flocculent matter. Clean smell (slightly fishy-earthy).	When opened, the flocculent matter in this was black (?) and the liquid putrid, with a strong smell of sulphuretted hydrogen. Not analysed.

CROYDON (BEDDINGTON) SEWAGE FARM, 1900.

Special Experiment—*continued.*

No. of Sample	168	168	169	169a
Nature of Sample	Final Filtration Effluent.	Small Duplicate.	Final (Surface Irrigation) Effluent off Rye-Grass.	Arable Field Effluent.
Drawn	Monday, 5th Nov. 1900, 12.50 noon.	—	Wednesday, 6th Nov. 1900, 12.40 noon.	6th Nov. 1900, 12 noon.
Temperature of sample	12·2° C. (54° F.)	—	12·8° C. (55° F.)	12·8° C. (55° F.)
Temperature of air	14·4° C. (58° F.)	—	13·3° C. (56° F.)	13·9° C. (57° F.)
If jointed or incubated	—	Jointed and on top of incubator 6th Nov.; inside 14th. Nov.	—	Jointed and on top of incubator 7th Nov.; inside 15th Nov.
Analysed	6th November 1900	27th Nov. 1900.	7th Nov. 1900.	Opened 19th Nov. 1900.
Parts per 100,000 *by weight.*				
Ammoniacal nitrogen—	(B) (A)		(B) (A)	
(a) by direct Nesslerization	0·31 —	—	1·32 —	—
(b) by distillation	0·26 —	0·22	0·96 —	—
Albuminoid nitrogen	0·03 —	0·04	0·06 —	—
Nitrous ,,	None. —	0·29	0·04 —	—
Nitric ,,	0·35 —		0·04 —	—
Total nitrogen by Kjeldahl, *with* reduction (after making nitrite correction)	No sugar. 0·64 0·60	—	No sugar. 1·30 1·48	—
Blank	(0·17 in 1·06) (0·12 in 0·97)	—	(0·17 in 1·79) (0·12 in 2·20)	—
Correction for nitrite	None.	—	+ 0·02	—
"X" nitrogen	None.	—	0·20	—
Organic nitrogen by Kjeldahl, *with* reduction	0·03	—	0·28	—
Organic nitrogen by Kjeldahl, *without* reduction :—*				
(a) Taking ammonia by direct Nesslerization.	*None (– 0·12) (Nesslerized Nov. 27th)	—	None (– 0·56) (Nesslerized about Nov. 27th).	—
(b) Taking ammonia by distillation	None (– 0·07)	—	None (– 0·20)	—
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once*	0·04	—	0·24	—
,, ,, *after 4 hours.*	0·45	—	0·59	—
Oxygen absorbed from permanganate by sample incubated for 5 days at 26·7° C. (80° F.); *at once*	0·14 } Six days.	—	0·17 } Six days.	—
,, ,, *after 4 hours.*	0·60 }	—	0·58 }	—
Smell after incubation	Like that of No. 167, *i.e.*, not quite sweet. This is curious.	Clean, slightly fishy-earthy.	Distinct though faint smell like ammonia on shaking bottle.	—
Chlorine	7·34	—	7·70	—
Gases; Parts per 1,000 *by volume.*				
Oxygen (by cuprous chloride) :—				
(a) When sample was drawn	1·0	—	4·0	—
(b) ,, ,, ,, analysed	2·0, 1·75, 1·5 } three observers. Standard deteriorated	None, or practically none. (*New standard tubes*).	3·5, 4·0, 4·0 approx. } three observers.	—
Remarks	This again looked a beautiful effluent, just like tap water, with—one may say—no sediment. Smell clean and slightly fishy-earthy.	This is a very good effluent, though the aeration was so slight.	Lemon-coloured but clear, with a rather large mass of red-brown flocculent matter at bottom of bottle. Clean, fishy-earthy smell.	This effluent had a strong sewage smell when drawn. After incubation the sediment was black and the liquid strongly putrid. Not analysed.

**Note* to the Kjeldahl *without* reduction.—Most of the clear alkaline liquid was poured off, the remainder shaken up, and 10 c.c. of the muddy liquid taken for distillation. This brought the Kjeldahl out to 0·41 (as against 0·19 in the actual estimation with the clear liquid), without allowing for the volume of the solid.
This indicates absorption of ammonia.

BEDDINGTON SEWAGE FARM, 1900.

Special Experiment—*continued.*

172 Final Surface Irrigation Effluent.		172 Small Duplicate.	173 Final Surface Irrigation Effluent.	173 Small Duplicate.
Friday, 9th November 1900, 3.15 p.m. 11·1° C. (52 F.) 10·6° C. (51° F.). — 10th November 1900.		— — — Jointed and put on top of incubator 10th November; inside 17th November. Opened 27th November 1900.	Saturday, 10th November 1900, 1·45 p.m. 8·9° C. (48°F.) 10·6° C. (51° F.) — 12th November 1900.	— — — Jointed and put on top of incubator 12th November; inside 17th November 27th November 1900.
(Almost certainly same bottle) (A)	(B)		Almost certainly same (B) bottle. (A)	
—	—	—	— —	—
1·23	1·27	—	0·77 —	0·73
0·15	0·12	—	0·10 —	0·06
None. Done by oxalate.	None. None.	— — —	0·01 — — 0·20 —	0·21
No sugar. 1·79	1·71	— —	No sugar. 1·23 1·03	—
(0·12 in 2·67)	(0·13 in 2·64)	—	(0·13in1·91) (0·12in1·57)	—
None.	None.	—	+0·01	—
0·41	0·32	— —	0·15	—
0·56	0·44	— —	0·25	— —
—	*0·11 (November 27th)	— —	*none (−0·05) 27th Nov.	— —
—	0·42	—	0·08	—
— —	— —	— — —	— 0·78	— — —
— —	0·15 1·08	— — —	0·42 1·04 } Seven days.	— — — —
—	Putrid.	— —	No smell (sweet).	Sweet.
—	—	— —	7·30	—
—	—	—	—	—
2·5 2·75 } Two observers *Standards weakened.* Distinctly turbid, but with no appreciable sediment. Clean fishy-earthy smell.	— —	— — This sample was now *very* putrid, and the small amount of flocculent matter was dark grey in colour. Not analysed.	4·75 about 5·0 } Two observers. Standards weakened. This looked a good effluent, slightly lemon-coloured, with a small quantity of brownish flocculent matter in it. Clean, slightly fishy-earthy smell.	None, or practically none.
	* Muddy liquid (containing calcium oxalate) treated as in No. 168. Found:— Kjeldahl = 1·49, as against the original figure = 1·38. *This again indicates absorption.*		*Muddy liquid treated as in Nos. 168 & 172. Kjeldahl = 0·81 as against the original figure = 0·72. *Again absorption.*	

CROYDON (BEDDINGTON) SEWAGE FARM, 1900.

River Water alone and admixed with Effluent.

No. of Sample	44	45	46	47
Nature of Sample	General Final Effluent.	River Water 340 yards above Effluent Outfall (at B in Mr. Kershaw's plan).	River Water 130 yards below Effluent Outfall (at C in plan).	River Water 360 yards below Effluent Outfall (at D in plan).
Drawn	Monday, 26th February 1900, 4.35 p.m.	Monday, 26th February 1900, 4.15 p.m.	Monday, 26th February 1900, 5.5 p.m.	Monday, 26th February 1900, 5.30 p.m.
Temperature of sample	13·3° C. (56° F.)	12·2° C. (54° F.)	13·3° C. (56° F.)	11·1° C. (52° F.)
Temperature of air	——	——	——	——
If jointed or incubated	——	——	——	——
Analysed	27th February 1900.	27th February 1900.	28th Feb. 1900.	2nd March 1900.
Parts per 100,000, *by weight.*				
Ammoniacal nitrogen:				
(a) By direct Nesslerization	1·73 approx.	Turbid.	2·02 (?)	Turbid.
(b) By distillation	2·06	0·007	1·84	0·039
Albuminoid nitrogen	0·23	0·011	0·35	0·024
Nitrous ,,	0·07	None.	0·04	None.
Nitric ,,	0·54	0·708	0·47	0·729
Total nitrogen by Kjeldahl, *with* reduction (after making nitrite correction)	2·97	0·741	3·28	1·015
Blank	(0·40 in 5·10)	(0·40 in 1·59)	(0·40 in 5·63)	(0·40 in 2·03)
Correction for nitrite	+0·04	None.	+0·02	None.
"X" nitrogen	0·07	0·015	0·58	0·123
Organic nitrogen by Kjeldahl, *with* reduction	0·30	0·026	0·93	0·147
Organic nitrogen by Kjeldahl, *without* reduction:				
(a) Taking ammonia by direct Nesslerization.	0·39 approx.	——	——	——
(b) Taking ammonia by distillation	——	0·052	0·05	0·073
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once.*	0·80	0·41	0·57	0·11
,, ,, ,, *after four hours.*	2·06	0·85	1·92	0·43
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once*	6 Days. 0·43 / 2 Days. 0·54	*0·11 Six Days.	0·57	0·09
,, ,, ,, *after four hours.*	1·47 / 1·59	Too little to estimate. Six Days.	1·23	0·25
Smell after incubation	Strong earthy.	Sweet.	Slight earthy.	No smell.
Chlorine	6·46	1·52	6·18	2·02
Gases: Parts per by 1,000 *volume.*				
Carbon dioxide (free)	29·36	†25·30	29·29	17·25
Oxygen (boiled out)	4·76	7·52	3·51	6·34
Oxygen (by cuprous chloride):				
(a) when drawn	——	——	——	——
(b) ,, analysed	——	——	——	——
Nitrogen	14·54	14·75	14·61	14·98
Remarks	Distinctly brownish and turbid, with an appreciable amount of flocculent matter. Fishy-earthy smell. *Very* alkaline.	Comparatively colourless, but contained an appreciable amount of brownish flocculent matter. No smell. Alkaline. Much lime, but practically no sulphate in solution.	Opalescent and slightly brown, with a small amount of brownish flocculent matter. Decidedly alkaline. A great deal of lime and much sulphate in solution.	Clear, but with some greyish-brown aggregated organic matter. No smell, *i.e.* slightly earthy. Slowly alkaline. Much lime in solution, but not very much sulphate.

† In boiling out the gases, I filled a 250 c.c. flask in the forenoon and boiled out from this in the afternoon.

CROYDON (BEDDINGTON) SEWAGE FARM, 1900.

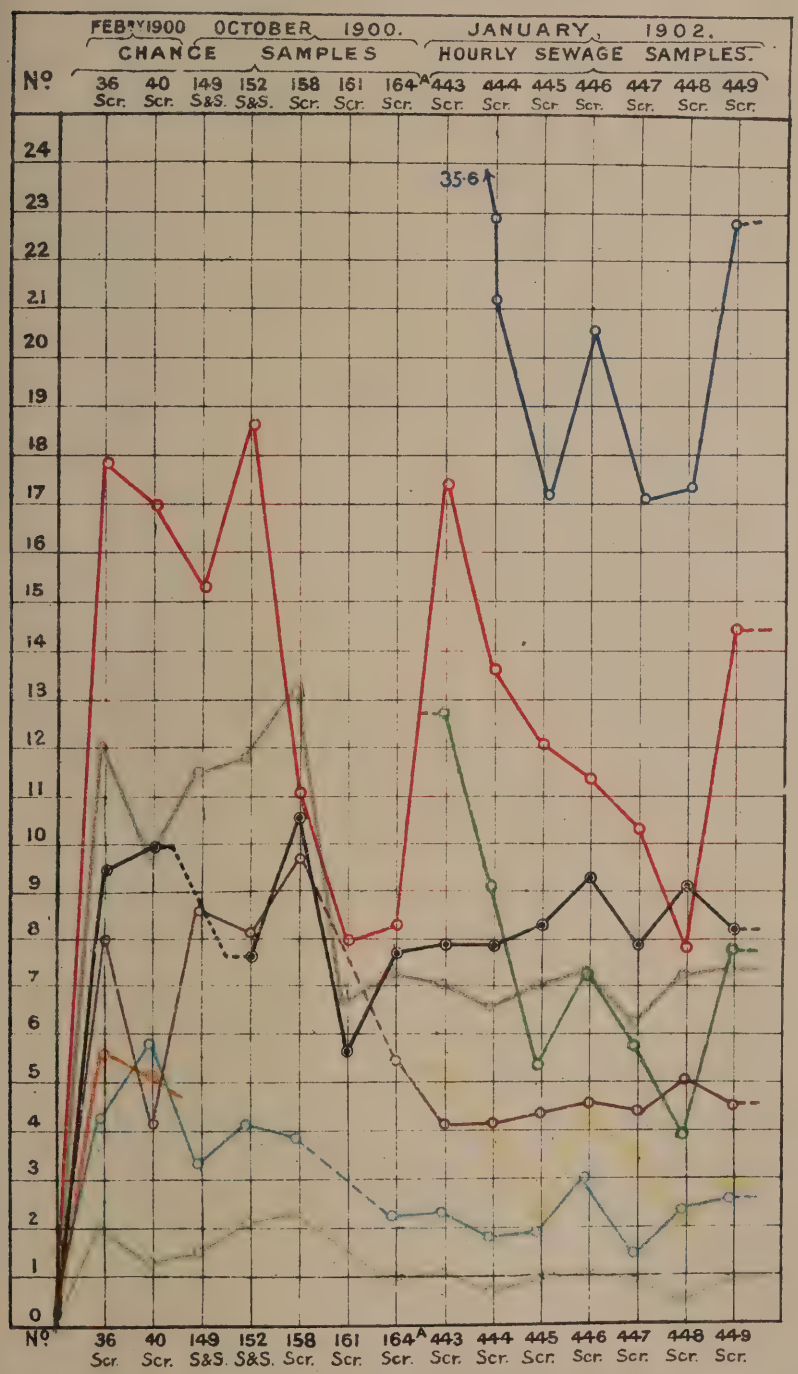
River Water alone and admixed wiith Effluent.

150a	154a	155b	156a	160a	166a
River Water above Effluent Outfall.	River Water above Effluent Outfall.	River Water containing Effluent drawn 360 yards below Effluent Outfall.	River Water from just above Effluent Outfall.	River Water containing Effluent drawn 360 yards below Effluent Outfall.	River Water containing Effluent drawn 360 yards below Effluent Outfall.
Wednesday, 3rd October 1900, probably about 2.30 p.m.	Tuesday, 9th October 1900, 2.30 p.m.	Thursday, 11th October 1900, 1.35 p.m.	Monday, 15th October 1900, 3.15 p.m.	Thursday, 18th October 1900, 2·45 p.m.	Friday, 2nd November 1900, 11.20 a.m.
11·7° C. (53° F.)	14·4° C. (58° F.)	10·6° C. (51° F.)	8·9° C. (48° F.)	11·1° C. (52° F.)	—
12·2° C. (54° F.)	17·8° C. (64° F.)	13·3° C. (56° F.)	10·0° C. (50° F.)	14·4° C. (58° F.)	—
Jointed and incubated 4th October.	Jointed and incubated 10th October.	Jointed and incubated 13th October.	Jointed and incubated, 16th October.	Jointed and incubated 19th October.	Not jointed, but placed on top of incubator, 3rd November.
13th October 1900.	18th October 1900.	19th October 1900.	23rd October 1900.	1st November 1900.	13th Nov. 1900.
—	—	—	—	—	—
—	—	—	—	—	—
—	—	—	—	—	—
		Distillation. Oxalate.	Distillation. Oxalate.	Distillation. Oxalate.	Distillation. Oxalate.
None. 0·12	0·45	0·53 0·56	0·51 0·48	0·50 0·54	0·53 0·51
—	—	—	—	—	—
—	—	—	*Note.*—In this case the 'couple' bottle, with contents, was weighed, to see if any loss in weight took place overnight through the stopper.	—	—
—	—	—	Oct. 23 = 271·0 grm.	—	—
—	—	—	Oct. 24 = 270·8 grm. This loss is therefore not appreciable, *i.e.*, less than 0·1%.	—	—
—	—	—		—	—
—	—	—	The "Blank" bottle, with contents, gave :— grm.	—	—
—	—	—	Oct. 23 = 289·1	—	—
—	—	—	Oct. 24 = 289·0	—	—
Quite sweet.	—	—	This loss is even less.	—	—
—	—	—	—	—	—
—	—	—	—	—	—
—	—	—	—	—	—
—	More than 6·0	—	—	—	—
(Two observers). Quite 7·0 c.c. Query: Standards weakening?	6·5, 6·0, 5·75 Three observers. Standards weakening?	7 or 8, 8·0, 7·5 Three observers. The standard tubes must have faded.	6 c.c. or over. (Three observers).	7·0, 6·5 Two observers. Standards weakening.	7·0 to 8·0 approximate. (But standards were old.)
—	—	—	—	—	—
—	*Note.*—There was a bubble of air or gas (about 0·3 c.c.) at top of bottle when opened.	—	Clear and nearly colourless, but with an appreciable amount of greyish sediment.	This was clear and nearly colourless, with a little sediment. No smell. *Note.*—There was a bubble at top of bottle.	The river was rather high when this sample was drawn.

Diagram No. 17.

CROYDON (BEDDINGTON) SEWAGE FARM.

SEWAGES. CURVES.



Nature of Sewage

Scr = *Screened*

S&S = *Screened & Settled*

REFERENCE

Parts per 100.000. by Weight.

Albuminoid Nitrogen ..... *Shewn thus*

Organic Nitrogen by Kjeldahl, with Reduction. .....

Organic Nitrogen by Kjeldahl, without Reduction. .....

Ammoniacal Nitrogen. .....

Total Nitrogen by Kjeldahl. with Reduction. .....

"Oxygen absorbed" from Permanganate at 26·7°C (80°F.) in four hours. .....

Chlorine (Combined) .....

Solids in Suspension (Gravimetrically) (Scale divided by 10). .....

Cellulose (still containing fat) .....

Parts per 100.000. by Volume.

Solids in Suspension (by Centrifuge) (Scale divided by 10)

Note

Figures in the Vertical line represent "Parts per 100.000."

Figures in the Horizontal line represent the numbers of the Samples analysed.

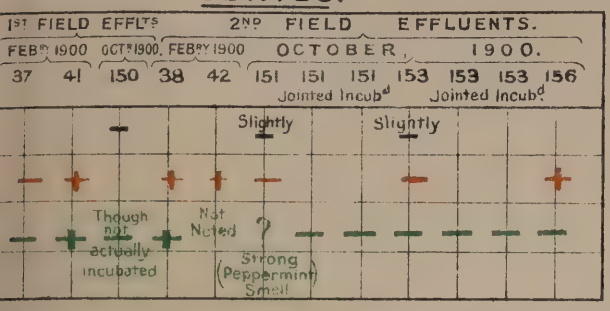
A dotted line is used when there is a break in the curve.

Weller & Graham, Ltd Litho London

DON (BEDDINGTON) SEWAGE FARM.

FIELD & 2ND FIELD EFFLUENTS.

CURVES.



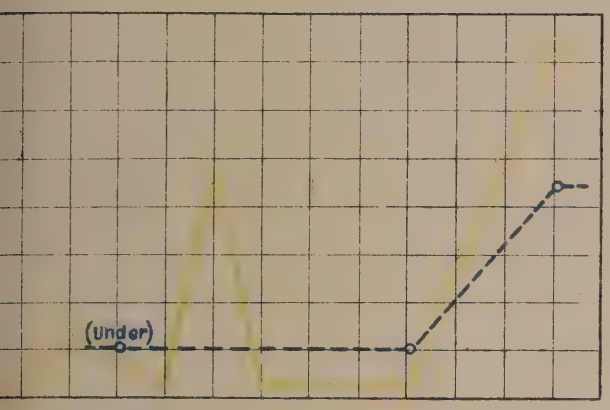
D

REFERENCE

Smell of Samples when drawn *Shewn thus* + or −

Scudder's Incubation Test + −

Incubation test as judged by Smell + −

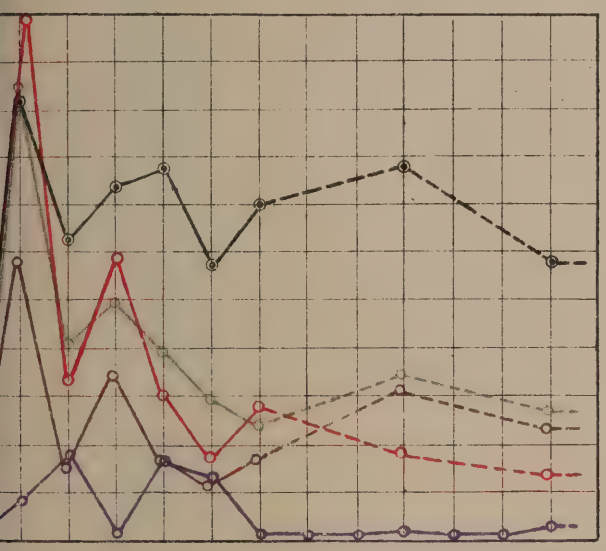


C

Parts per 1000, by Volume (C.C. per Litre)

Dissolved Oxygen when sample was drawn *Shewn thus* ——

Dissolved Oxygen when sample was analysed - - -



B

Parts per 100.000, by Weight.

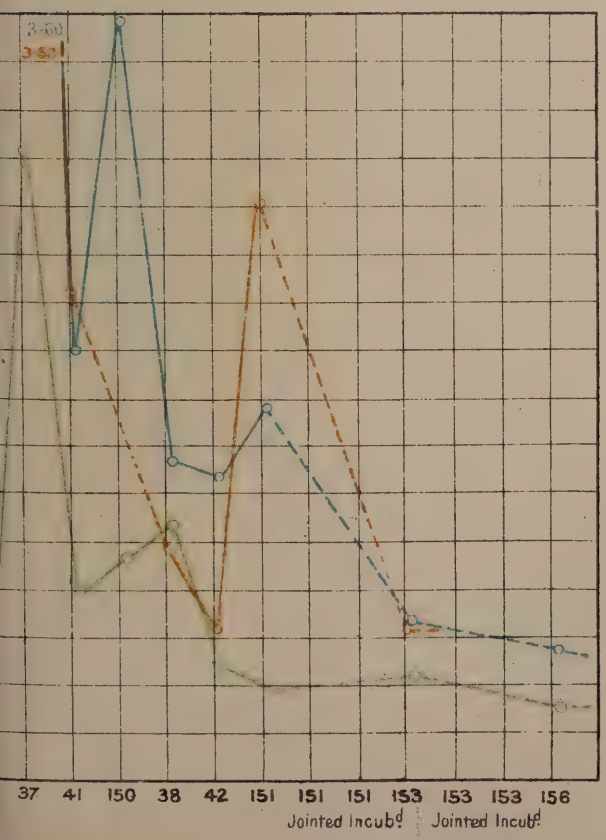
Ammoniacal Nitrogen *Shewn thus* ——

Total Nitrogen by Kjeldahl, with Reduction ——

Nitric + Nitrous Nitrogen (together) ——

"Oxygen absorbed" from Permanganate at 26·7°C (80°F.) in four hours ——

Chlorine (Combined) ——



A

Parts per 100.000, by Weight.

Albuminoid Nitrogen *Shewn thus* ——

Organic Nitrogen by Kjeldahl, with Reduction ——

Organic Nitrogen by Kjeldahl, without Reduction ——

Note

"Jointed" Indicates a sample jointed and allowed to stand at laboratory temperature.

"Incubated" Indicates a sample jointed and allowed to stand for five days or longer at a temperature of 26.7°C (80°F.).

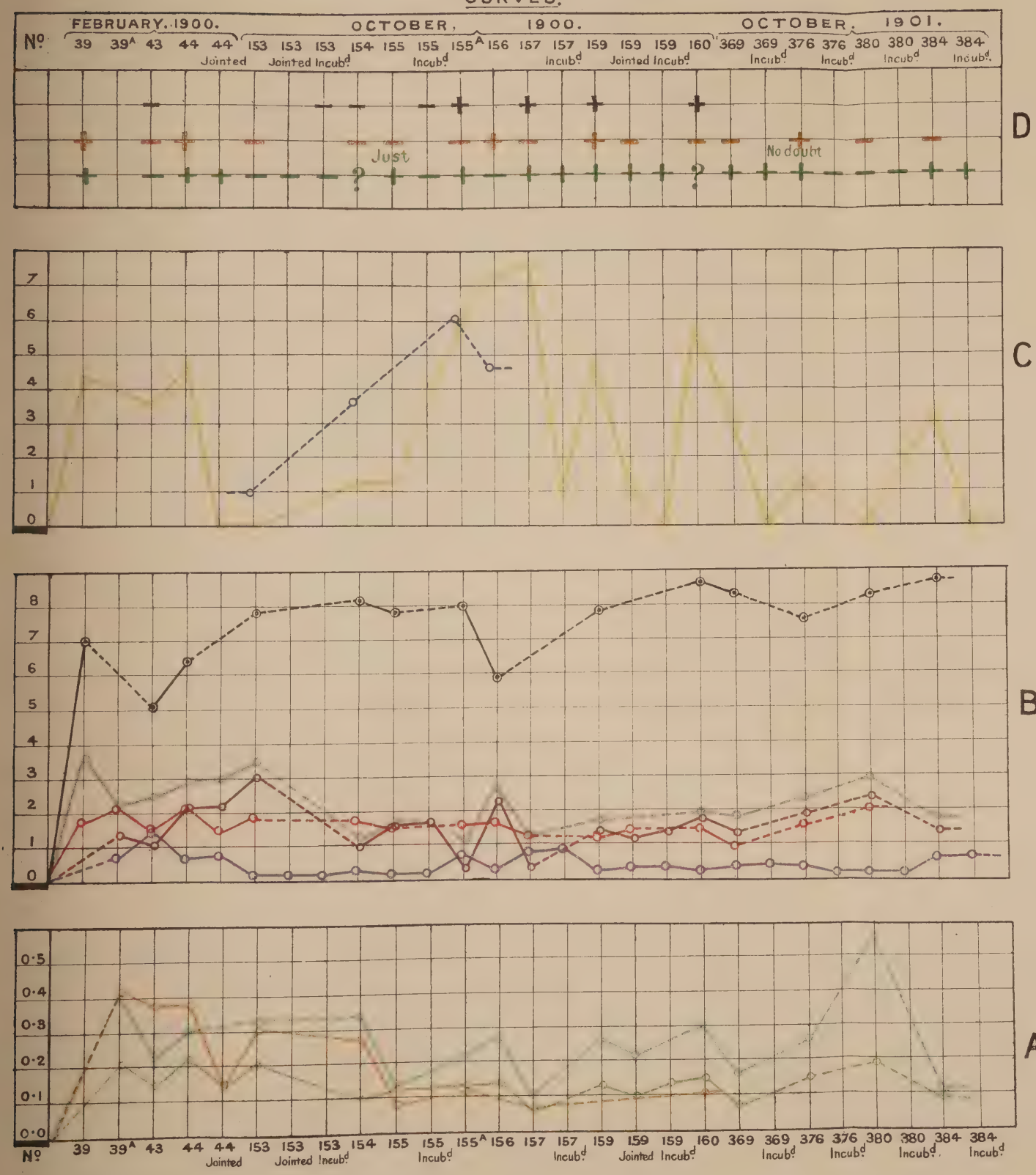
Figures in the Vertical line represent "Parts per 100, 000"
Figures in the Horizontal line represent the numbers of the Samples analysed.
A dotted line is used when there is a break in the curve.

Diagram No 19.

CROYDON (BEDDINGTON) SEWAGE FARM.

3RD FIELD, FINAL AND GENERAL EFFLUENTS.

CURVES.



REFERENCE

Smell of Samples when drawn Shewn thus + —

Scudder's Incubation Test + —

Incubation test as judged by Smell + —

Parts per 1.000, by Volume (C.C. per Litre)

Dissolved Oxygen when sample was drawn Shewn thus ——

Dissolved Oxygen when sample was analysed - - - - - -

Parts per 100.000, by Weight.

Ammoniacal Nitrogen - - - - Shewn thus ——

Total Nitrogen by Kjeldahl, with Reduction - - - - - -

Nitric + Nitrous Nitrogen (together) - - - - -

"Oxygen absorbed" from Permanganate at 26·7°C (80°F.) in four hours - - - - - -

Chlorine (Combined) - - - - - -

Parts per 100.000. by Volume.

Solids in Suspension (by Centrifuge) (Scale divided by 10)

Parts per 100.000, by Weight.

Albuminoid Nitrogen - - - - Shewn thus ——

Organic Nitrogen by Kjeldahl, with Reduction - - - - - -

Organic Nitrogen by Kjeldahl, without Reduction - - - - - -

Note

"Jointed" Indicates a sample jointed and allowed to stand at laboratory temperature.

"Incubated" Indicates a sample jointed and allowed to stand for five days or longer at a temperature of 26.7°C (80°F.).

Note

Figures in the Vertical line represent "Parts per 100.000."

Figures in the Horizontal line represent the numbers of the Samples analysed.

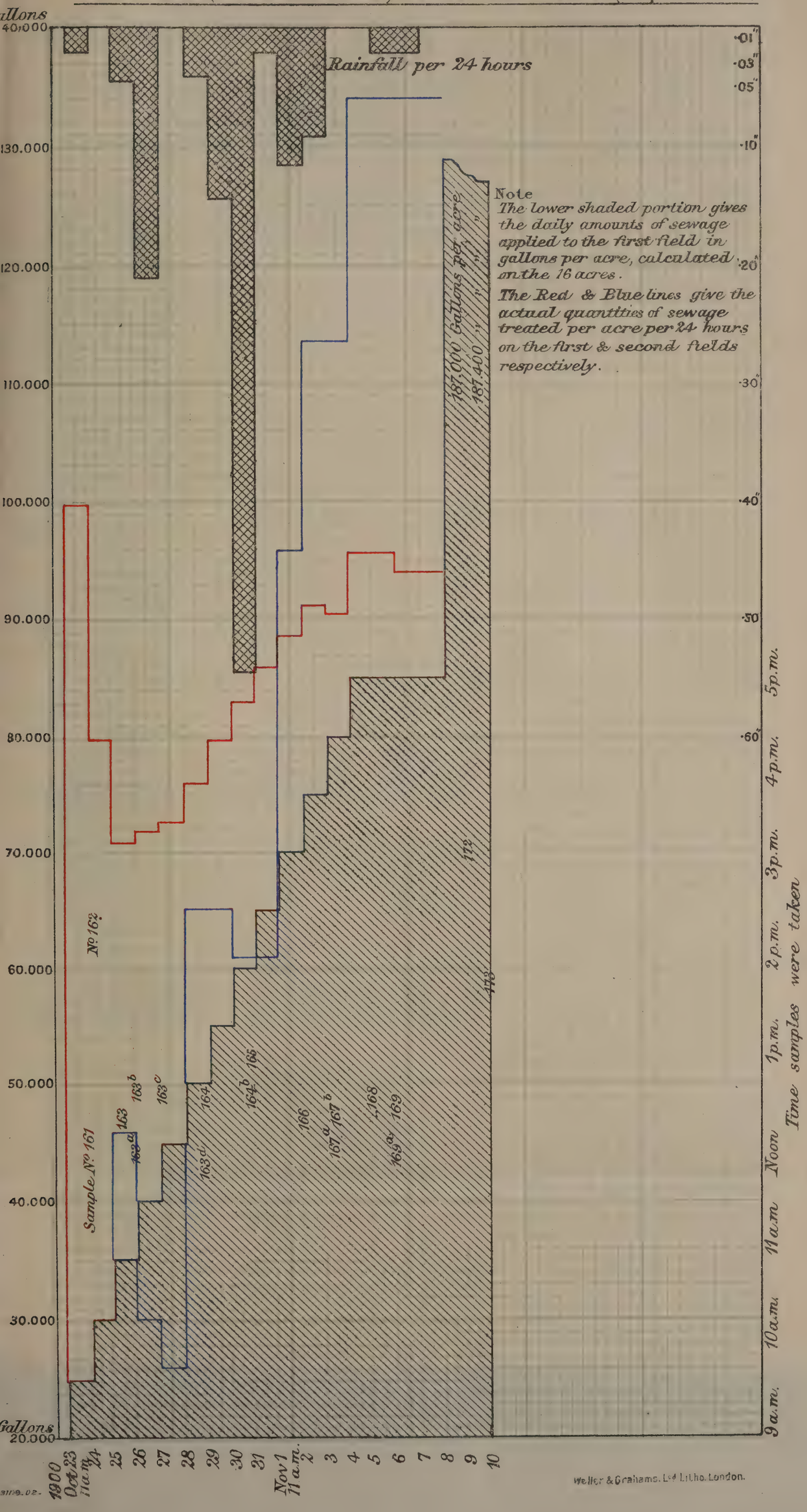
A dotted line is used when there is a break in the curve.

3332 .B.02

Weller & Graham Ltd Litho. London.

Diagram No. 20.
(Engineering Report Diagram).

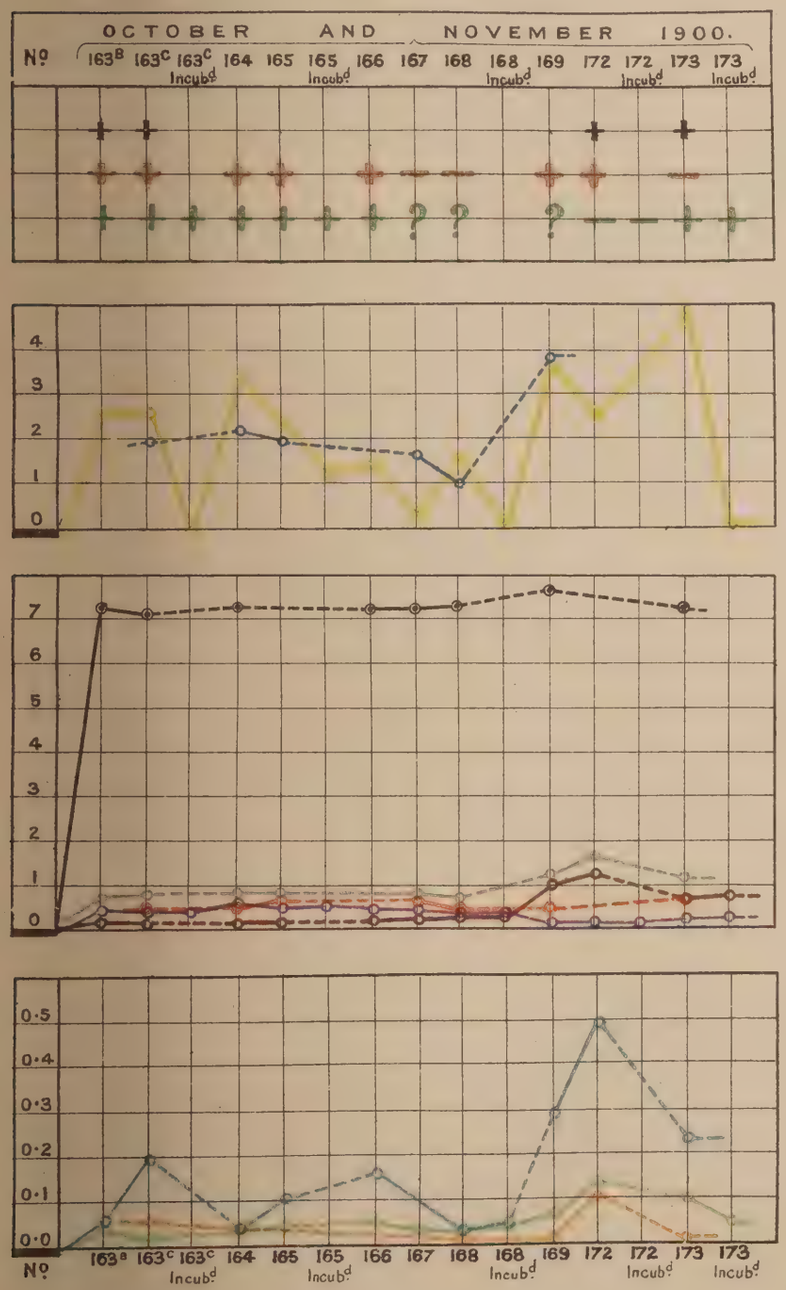
CROYDON (BEDDINGTON) SEWAGE FARM. *(Experiment)*



Weller & Grahams. Ltd Litho. London.

Diagram No. 21.

CROYDON (BEDDINGTON) SEWAGE FARM.
SPECIAL EXPERIMENT
2ND FIELD, (FINAL FILTRATION) EFFLUENTS.
CURVES.



REFERENCE

Smell of Samples when drawn Shewn thus + or —

Scudder's Incubation Test + —

Incubation test as judged by Smell + —

Parts per 1000, by Volume (C.C. per Litre)

Dissolved Oxygen when sample was drawn Shewn thus

Dissolved Oxygen when sample was analysed

Parts per 100.000. by Weight.

Ammoniacal Nitrogen Shewn thus

Total Nitrogen by Kjeldahl, with Reduction

Nitric + Nitrous Nitrogen (together)

"Oxygen absorbed" from Permanganate at 26·7°C (80°F.) in four hours

Chlorine (Combined)

Parts per 100.000. by Weight.

Albuminoid Nitrogen Shewn thus

Organic Nitrogen by Kjeldahl, with Reduction

Organic Nitrogen by Kjeldahl, without Reduction

Note

Figures in the Vertical line represent "Parts per 100.000."

Figures in the Horizontal line represent the numbers of the Samples analysed.

A dotted line is used when there is a break in the curve.

"Incubated" Indicates a sample jointed and allowed to stand for five days or longer at a temperature of 26.7°C (80°F.).

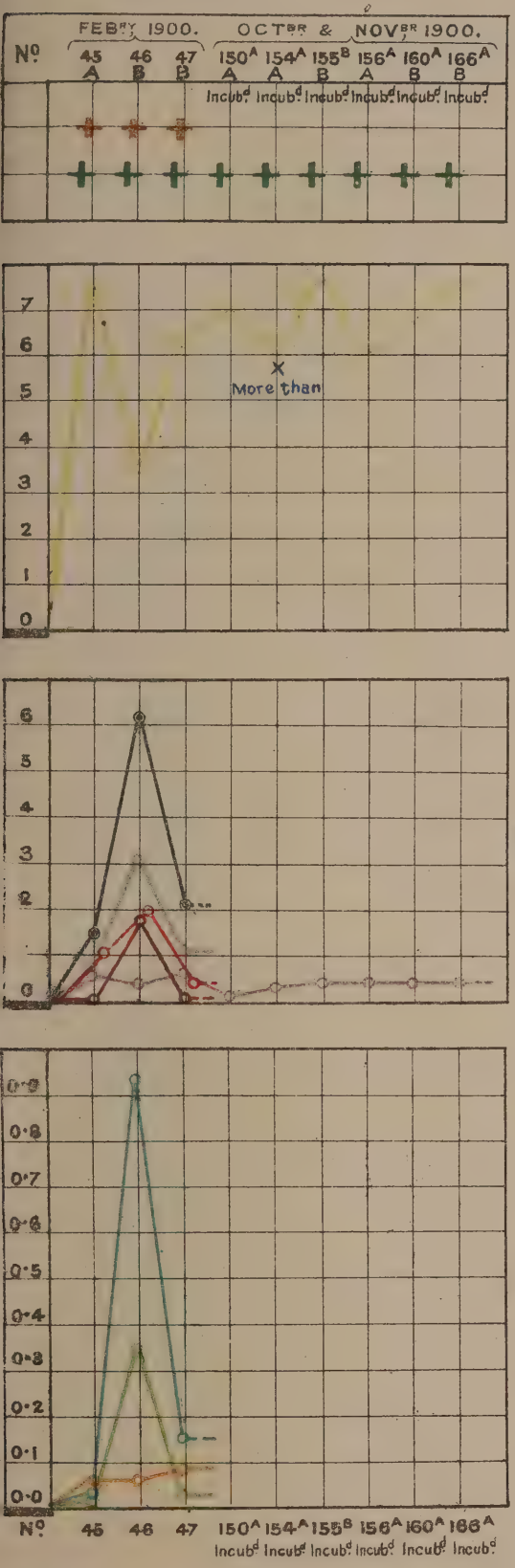
3332. 8. 02

Weller & Graham. Ltd Litho. London.

Diagram No. 22.

CROYDON (BEDDINGTON) SEWAGE FARM.

RIVER WATER. CURVES.



Note

Figures in the Vertical line represent "Parts per 100.000."

Figures in the Horizontal line represent the numbers of the Samples analysed.

A dotted line is used when there is a break in the curve.

Note.

'A' Indicates a sample drawn from above Effluent Outfall.
'B' " " " " " below " "

REFERENCE

Scudder's Incubation Test ..... + —

Incubation test as judged by Smell + —

Parts per 1.000, by Volume (C.C. per Litre)

Dissolved Oxygen when sample was drawn Shewn thus ——

Dissolved Oxygen when sample was analysed .....

Parts per 100.000, by Weight.

Ammoniacal Nitrogen ..... Shewn thus ——

Total Nitrogen by Kjeldahl. with Reduction. .....

Nitric + Nitrous Nitrogen (together) ..... ——

"Oxygen absorbed" from Permanganate at 26·7°C (80°F.) in four hours. ..... ——

Chlorine (Combined) ..... ——

Parts per 100.000, by Weight.

Albuminoid Nitrogen ..... Shewn thus

Organic Nitrogen by Kjeldahl, with Reduction. ..... ——

Organic Nitrogen by Kjeldahl, without Reduction. .....

Note.

"Incubated" Indicates a sample jointed and allowed to stand for five days or longer at a temperature of 26.7°C (80°F.).

Weller & Graham. Ltd Litho. London.

LEICESTER SEWAGE FARM

Chemical Report.

1. Situation of farm.—Beaumont Leys, about two miles from Leicester.
2. Total acreage of farm.—1,699 acres.
3. Total irrigable area.—1,350 acres.
4. Average area irrigated at one time.—About 337 acres.
5. Population draining to farm.—197,000.
6. Population per acre irrigated.—146.
7. Gallons of sewage per head per day.—36·8.
8. Dry weather flow of sewage per 24 hours.—7,250,000 gallons.
9. Gallons of sewage treated per acre per 24 hours.—21,500.
10. Gallons of sewage treated per acre per 24 hours, on the assumption that each acre of the irrigable area is under sewage all the time.—5,370.
11. Character of the sewage.—About three-fourths domestic and one-four t trade refuse.
12. Method of treatment.—Screening, settling tanks, surface irrigation and filtration combined.
13. General character of the soil and subsoil.—Stiff clayey soil, overlying dense clay.
14. Separate or combined sewerage system.—Partially separate.
15. The final effluent is discharged into Anstey Brook, flowing into River Soar.
16. Number of years farm in operation (before 1900)—9 years.

LEICESTER SEWAGE FARM.

The Leicester Sewage Farm dates from the year 1890. It may be taken as affording a typical instance on a large scale of broad irrigation over clay soil, combined with filtration. As the farm slopes on both sides from a central ridge, the effluent can be easily picked up from the drains at the foot of one field and sent over a second, third, or even a fourth piece of ground. In the Engineering Report* Mr. Kershaw has entered fully into the system of treatment adopted at this farm, and has also discussed the question of what quantities of liquid relatively are dealt with on such ground by broad irrigation and filtration respectively. It is obvious, however, that true filtration through a clay soil and subsoil cannot be rapid, for we may not look upon the escape of sewage through large cracks in the soil into the drains beneath as coming under that category. The effluents are therefore to be regarded in the main as *surface irrigation effluents*, mixed with a varying quantity of filtration effluent, from two, three, or even four treatments of roughly screened and settled sewage. The capacity of the settling tanks, however, is so small at Leicester (holding as these do less than 10 per cent. of the normal flow) that the settlement is not good, though considerable further deposition takes place in the carriers. The screenings from the pumping station are sold. The sludge at the farm is partly ploughed into the ground and partly sold to farmers.

The average depth of the drains is 4 feet, though, when new ones are put in, the depth of these is only 3 feet. There is practically no subsoil water on the farm.

With reference to the question of percolation through clay soils, Dr. A. P. Aitken of Edinburgh, who as chemist for many years to the Highland and Agricultural Society has had a wide experience on the subject, writes as follows (he has kindly allowed me to quote this) :—

> "The permeability of clay land is a thing you cannot generalise about. Every field has its own kind of clay, and nothing but practical experiment can show whether the drains are drawing well, or over what area they are drawing. In most clays of a very stiff kind almost nothing is drawn through the soil more than a yard or so on either side of a four-foot deep drain, but you can easily test the matter for yourself by digging shallow holes on the top of the ridges, filling them with salt water, and seeing how soon the chloride is visible in the drainage water. After heavy liming, a heavy clay becomes somewhat porous, but it will take a long time for lime to ameliorate by granulation a layer of clay four feet thick."

---

* Part IV. :—Engineering and Practical Report.

Soil and Subsoil.

Mr. Kershaw describes these as follows :—"The soil of this farm is of clay. The surface soil over the greater portion is of a stiff clayey nature, 6in. to 12in. deep, over 2ft. 6in. to 3ft. of yellow clay, overlying hard boulder clay and the Keuper marl. About 25 to 30 acres in the vicinity of the Anstey Brook is of rather a better nature, having a certain depth of alluvial soil."

The mechanical analysis of the soil, both unboiled and boiled before elutriation, is given in the following table. The stiff clay subsoil was not analysed, excepting for the quantity of lime that it contained :—

Name of Fraction.	Surface Soil per Cent.						Subsoil per Cent.
	Not Boiled.			Boiled.			
	Not Ignited.	Ignited.	Difference.	Not Ignited.	Ignited.	Difference.	
Fine "Gravel" (above 2 m.m. diameter) -	5·66	4·63	1·03	9·92	9·45	0·47	—
Coarse "Sand" („ 1 m.m. „) -	2·38	1·81	0·57	1·60	1·20	0·40	—
Coarse "Sand" („ 0·5 m.m. „) -	1·28	0·97	0·31	1·40	1·07	0·33	—
Medium "sand" („ 0·25 m.m. „) -	2·28	1·72	0·56	1·60	1·28	0·32	—
"Sand" (0·25 to 0·05 m.m.) - - -	37·02	34·16	2·86	37·16	34·54	2·62	—
"Silt" (0·05 to 0·01 m.m.) - - -	35·23	29·75	5·48	27·93	23·52	4·41	—
"Dust" from (0·01 m.m. downwards, which settles from water in 24 hours) - -	10·98	9·30	1·68	13·27	11·21	2·06	—
"Clay" (*i.e.*, the still finer residue precipitated from water by dilute nitric acid) -	4·61	3·88	0·73	4·78	4·01	0·77	—
Loss on ignition (separate determination) -	—	11·52	—	—	13·05	—	—
	99·44	97·74	13·22	97·66	99·33	11·38	—
Real specific gravity of soil dried at 110° C.	2·520	—	—	—	—	—	—
Apparent specific gravity - - - -	1·197 / 1·292	—	—	—	—	—	—
Number of particles in 1 gramme of the ignited soil (approx.) - - - -	2,204,335,000		—	—	—	—	—
Number of particles in 1 c.c. of the . . . ignited soil (approx.) - - - -	2,744,416,680		—	—	—	—	—
Weight of water retained by 100 grammes of the soil when fully drained - -	47·5(?)	—	—	—	—	—	—
Parts per 100,000.							
Lime dissolved by water in 24 hours - -	0·073	—	—	0·017	—	—	—
Lime dissolved by water saturated with carbonic acid, in 48 hours - - - -	0·554	—	—	0·467	—	—	—

For a discussion of the figures given in this table, the reader is referred to the Section upon Soils, page 275.

Volume Treated per Acre, etc.

The sewage contains about a quarter of its volume of trade refuse, which comes from 11 dye works, 10 wool-scourers' and spinners' works, two fellmongers and one currier. This refuse is thus largely of an objectionable nature.

The normal dry weather flow of sewage is 7,250,000 gallons per 24 hours, and the population draining to the farm 197,000. This gives 37 gallons of sewage per head of population and 146 persons per acre irrigated. But, since 10,000 persons on the pail system are included in the 197,000, the above figure for population per acre ought—strictly speaking—to be reduced slightly.

The trade refuse has not yet been investigated for the Commission, but if we assume it to be equally amenable to treatment with the sewage (which it probably is not), this would add the equivalent of about half as many people again, *i.e.*, would increase the number draining to the farm from 146 to about 220 persons per acre (because the volumes of domestic sewage and trade refuse are roughly as 52 : 28, leaving the remaining 20 volumes of well and subsoil water out of account).

The water supply is only 19 gallons per head, so the combined sewage must be made up roughly of—

Domestic sewage - - - - - -	52 per cent.
Trade refuse - - - - - -	28 ,, ,,
Well and subsoil water getting into the sewers -	20 ,, ,,

Mr. Kershaw has described fully in his Report* how storm water at Leicester is dealt with, twice the dry-weather flow being treated on the farm.

The irrigable area at the Leicester farm is 1,350 acres, of which 448 are arable and 902 pasture (*i.e.*, 1 : 2). About one-fourth of this surface is irrigated at a time, an acre therefore dealing with 21,500 gallons in 24 hours. But if we make, *for purposes of comparison*, our usual assumption that the entire irrigable area is under sewage all the time, *then one acre at Leicester treats* 5,370 *gallons of sewage per* 24 *hours throughout the whole year.*

Four visits were paid to Leicester, viz., in November, 1899, August and September, 1900, September and October, 1901, and February, 1902.

Nature of Sewage (*Diagram No.* 23).

As already stated, this is screened and settled, but the settlement is only for about two hours, or a little longer. The sewage, though of moderate strength as regards nitrogenous matter, contains relatively a large proportion of oxidizable substance as measured by the "oxygen absorbed" test, this being without doubt due to some of the manufacturing refuse present. The sewage arrives at the farm in a well broken-up condition.

Eight samples were analysed—five chance ones and three sets of hourly samples drawn in equal quantities every hour for three days. The hourly samples will therefore be somewhat weaker than a true average, taken according to the rate of flow, would have been; but probably not very much weaker, seeing that a pumping scheme always has a tendency to equalise the hourly variations. The chance samples were taken in November, August and September 1900, and the hourly samples in February 1902. Excepting No. 136, which was drawn when only one tank was in use, and which would therefore contain more than its fair share of suspended solids, the chance samples were distinctly the weaker, though drawn usually about noon. In making any approximate calculations, therefore, as to purification, etc., the figures obtained from the hourly samples will be mainly relied upon, all the more, as no rain fell while these were being drawn; although there were three inches of snow on the ground at the time, no thaw occurred.

All the samples, chance and hourly ones, contained very considerable quantities of sediment. In No. 136, a chance sample, the sediment was very hard to break up, but in the hourly samples the solids were rather finely divided; it will be seen that

* Part IV.: Engineering and Practical Report.

hair was noted as present in all the three latter. The fact of 34 to 35 parts per 100,000 of suspended solids being found in the hourly samples proves that the settlement in the tanks is only moderate (Mr. Kershaw states in his Report that about half of the suspended solids of the sewage are deposited in the tanks). Still, the system adopted at Leicester of (partial) settlement in tanks and carriers, with irrigation first over arable land and then over pasture, is sufficient to prevent the soil becoming permanently choked, for Mr. Kershaw has observed that the roots of the grass are not injured by clogging.

All the samples that were tested for their reaction were alkaline. Nos. 469 and 470 (hourly samples) are noted as having a smell like that of hippuric acid. The temperatures of the chance samples did not vary greatly, though they were drawn in November, August and September, the limits being 12·7° to 17·7° C. (55° to 64° F.).

The following is a summary of the more important analytical results :—

	Average.
Total nitrogen—(*a*) 5 chance samples (2·90 to 8·61) - - - -	5·57
(*b*) 3 sets of hourly samples (7·32 to 9·16) - - - -	8·12
Ammoniacal nitrogen—(*a*) 5 chance samples (2·90 to 8·61) - -	5·57
(*b*) 3 sets of hourly samples (7·32 to 9·16) - - - -	8·12
Total organic nitrogen—(*a*) 5 chance samples (1·18 to 2·41) - -	1·68
(*b*) 3 sets of hourly samples (2·10 to 2·53) - - - -	2·34
Albuminoid nitrogen—(*a*) 5 chance samples (0·66 to 1·70) - -	1·11
(*b*) 3 sets of hourly samples (0·97 to 1·44) - - - -	1·19
"*Oxygen absorbed*" *in* 4 *hours at* 26·7° C. (80° F.)—(*a*) 5 chance samples (7·77 to 16·41) - - - - - - - -	12·45
(*b*) 3 sets of hourly samples (20·28 to 24·83) - - - -	22·35
Chlorine—(*a*) 5 chance samples (3·51 to 11·94) - - - -	8·10
(*b*) 3 sets of hourly samples (12·50 to 13·84) - - - -	13·38
Chlorine in water supply - - - - - - -	1·93
Chlorine in subsoil water (one sample) - - - -	1·96
Ratio of Ammoniacal Nitrogen to Chlorine—3 sets of hourly samples. {1 : 2·25, 1 : 2·59, 1 : 2·66} - -	1 : 2·57
Ratio of Ammoniacal Nitrogen to Chlorine, after deducting the chlorine of the water supply—3 sets of hourly samples. {1 : 1·93, 1 : 2·19, 1 : 2·29} -	1 : 2·14
Solids in suspension—3 sets of hourly samples (33·6 to 34·8) - -	34·1
Solids in Suspension by Centrifuge (*Volumes*)—3 sets of hourly samples (160 to 261) - - - - - - - - - -	196
Ratio of Solids in Suspension to Centrifuge solids {1 : 7·5, 1 : 5·0, 1 : 4·8} - - -	1 : 5·8
Cellulose still containing fat—3 sets of hourly samples (11·80 to 12·80) (one extraction with dilute alkali and one with dilute acid)- -	12·24
Ratio of celluloses still containing fat to suspended solids—3 sets of hourly samples. {1 : 2·9, 1 : 2·6, 1 : 2·8} -	1 : 2·8
Cellulose—2 sets of hourly samples (6·56 and 5·80) (extraction with alkali, acid and ether) - - - - - - - -	6·18
Ratio of celluloses to suspended solids 2 sets of hourly samples. {1 : 5·3, 1 : 5·8} - - - - -	1 : 5·6

A study of the Tables of Analysis and Curves of these Leicester sewages shows great variations in the chance samples but comparative evenness in the three sets of hourly ones, though No. 469 (the first of the hourly sets) is on the whole distinctly stronger than the other two, and contains relatively much more suspended solids as measured by *volume.*

Speaking roughly, in all the samples of sewage the different curves bear a tolerable resemblance to one another, and in the hourly samples (excepting for volume solids) this resemblance is very marked. The latter contained an average of 8·12 parts total nitrogen and 2·34 parts organic nitrogen (of which almost exactly half was albuminoid), while they gave the high figure of 22·35 for "oxygen absorbed." The suspended solids averaged 34·1 parts, a point which has been already referred to as showing that the settlement in the tanks is not very good. The sewage which the Leicester farm has to treat is thus one of considerable strength.

The *Ratio between the average figures for Organic Nitrogen and "Oxygen absorbed"* is 1 : 7·4 in the chance samples,* and 1 : 9·6 in the hourly ones—not a good agreement, and, further, a ratio far in excess of that obtained from any purely domestic sewage.

The Average Ratio of Albuminoid Nitrogen to "Oxygen absorbed" in the five chance samples is 1 : 11·9, and in the three sets of hourly samples 1 : 19·0. In the chance samples this ratio is very uneven, but in the hourly samples even; it will be noted that in the latter the ratio is a very high one.

The hourly samples all contained small quantities of nitrate, a proof of the entrance of subsoil water into the sewers. Unfortunately the chance samples were not tested for this, though no doubt some of them contained it.

The agreement between the curves for *ammoniacal* and for *total nitrogen* is very marked, and there is (excepting in sample No. 1, a weak sample taken after heavy rain, which must evidently have contained some nitrate) a fair agreement between the curves for total and ammoniacal nitrogen, on the one hand, and for total organic and albuminoid nitrogen on the other.

As regards *organic nitrogen,* excepting in the case of No. 1, only the Kjeldahl method *with* reduction was used. No comparison of those two methods can therefore be made here.

In the hourly samples, the "*oxygen absorbed*" curve follows that of the *total nitrogen* well, and they keep a pretty constant ratio; in the chance samples the curves follow one another but the ratios vary greatly.

The *Chlorine* curve agrees well with that for *Ammoniacal Nitrogen* in the hourly, but not in the chance samples; this is of course what one would expect in a sewage containing so much manufacturing refuse, which is allowed into the sewers *at irregular intervals.*

No estimations of *suspended solids* were made in the chance samples either volumetrically or gravimetrically. Those in the hourly samples have been already referred to. The ratios between the *suspended solids* estimated (a) gravimetrically and (b) volumetrically by the centrifuge agree well in two out of three cases, the average of two being 1 : 4·9, and of three 1 : 5·8 (the Cambridge ratio was 1 : 6·0). The ratios between the *celluloses* and *suspended solids* agreed well, but here again only two cellulose results could be taken, a probable error occurring in the middle estimation. The ratio was 1 : 5·6 (Cambridge 1 : 5·9). Further estimations would be required in order to determine how far the centrifuge was of value for the *approximate* determination in a few minutes of the relative amounts of suspended solids and cellulose in the Leicester sewage; but probably it would be found useful.

1*st Field Effluents.* (*Diagram No.* 24.)

Five of these were examined, two (Nos. 2 and 8) drawn in the month of November and three (Nos. 125, 127a and 128a) in August. They are all given by Mr. Kershaw as *mixed surface and filtration effluents.* In temperature they of course varied consider-

* The later results would seem to indicate that the figure for organic nitrogen in the chance samples is too low.

ably, viz., from 7·2° to 21·6° C. (45° to 71° F.), a much greater variation than in the case of the sewages. All of these effluents were of a brownish colour, with more or less suspended matter, were alkaline in reaction, and had a putrid or sewage smell when they came to be analysed.

The samples are too few in number to allow of many conclusions being drawn, but the Tables of Analysis and Curves show that the larger part of the impurities in the sewage is taken out by this first (arable) field. The average albuminoid nitrogen in the five samples was 0·37 and the average "oxygen absorbed" 6·42. They varied greatly as regards total nitrogen and contained no nitrate when analysed; they may in fact be regarded as sewage half purified from its organic matter, and especially from its suspended solids.

Final 2nd and 3rd Field and General Effluents. (*Diagram No.* 24).

Thirteen samples of these were examined, viz., 8 second-field effluents (5 in duplicate), and 5 third-field and general effluents (4 in duplicate); excepting No. 3, however, the third-field effluents were only partially analysed. All the second-field effluents are given by Mr. Kershaw as *mixed surface and filtration effluents*, while of the five third-field and general effluents three (Nos. 3, 352 and 353) *are surface effluents only.* No. 3 was a good effluent, but very dilute from rain; Nos. 352 and 353 were fair, especially the second. The second-field effluents were drawn in the months of August and September, the third-field ones in November, September, and October. The temperatures of the eight second-field effluents (November, August, and September) varied between 6·6° and 20° C. (44° and 68° F.), while the limits of the five third-field and general effluents (November, September and October) were 9·4° and 16·6° C. (49° and 62°F.). Though considerable, these variations are rather less than one would have expected from a (mainly) surface irrigation farm in those months.

The effluents were either clear, slighty opalescent, or in one or two cases more or less turbid. Their colour was brown or sometimes yellow, and there was always some flocculent matter present, for the most part, no doubt, fragments of weed from the drains, tinged with oxide of iron. Every sample was alkaline, some of them strongly so. When they came to be analysed the smell was quite clean, *i.e.*, usually earthy, though sometimes inclining to a seaweed or fishy odour. In the few samples tested there was much lime and sulphate in solution.

The following figures show some of the more important average results from the examination of 8 to 13 effluents, most of which were over two fields—(8 for Total and Organic Nitrogen; 9 for Ammoniacal and Albuminoid Nitrogen; 13 for Nitric + Nitrous Nitrogen and for "Oxygen absorbed"). Details are to be found in the Tables of Analysis and Curves:—

	Average.
Total Nitrogen (1·84 to 3·64)	2·53
Ammoniacal Nitrogen (0·59 to 2·81)	1·65
Albuminoid Nitrogen (0·07 to 0·35)	0·20
Total Organic Nitrogen (0·18 to 0·73)	0·45
Nitric + Nitrous Nitrogen together (0·0 to 1·73)	0·51
"Oxygen absorbed" from permanganate at 26·7° C. (80° F.) in four hours (1·70 to 4·47)	2·50
Incubator test (as judged by smell)	92% passed (13 samples tested.)

The Analytical Tables and Curves show that these effluents varied considerably in quality, though it cannot be said, speaking generally, that there were any sufficiently marked differences, dependent upon the season of the year in which they were drawn, to allow of deductions in this respect, excepting that the figures for dissolved oxygen in Nos. 3, 4 and 9, drawn in November, were much higher than in any other case; but this was evidently due to the lower temperature in November. The chlorine curve was a very uneven one, and in fact this applies to the curves generally, the least irregular of them being that for total nitrogen.

Excepting in the three samples already mentioned, in which the *Dissolved Oxygen* averaged fully 5 c.c. per litre, none of the other effluents showed more than about

1 c.c. when they came to be analysed, and in a good many of them it was apparently absent altogether. But the copper chloride method for oxygen determination is not at all suitable for brown-coloured effluents like those from Leicester, and the results are doubtless therefore distinctly too low.

The dissolved free carbonic acid in the three samples boiled out for this varied very much (18 to 40 c.c. per litre), but in no case was it large, this indicating a surface rather than a filtration effluent.

In the few cases noted, the smell of the effluent when drawn was not necessarily a criterion of its keeping property.

The *Ammoniacal Nitrogen* in nine final or general effluents varied between 0·59 and 2·81, average 1·65; it thus constituted, roughly, about two-thirds of the total nitrogen.

The *Albuminoid Nitrogen* in nine final and general effluents (6 of them over two fields and 3 of them wholly or partly over three fields) varied between 0·07 and 0·35, the average being 0·20. All of the samples kept sweet on incubation with the exception of Nos. 9 and 131 (alb. nitrogen=0·15 and 0·35). With regard to this last sample, Mr. Kershaw noted when it was drawn that the bullocks in the field had probably stirred up some sediment.

As regards "*Oxygen absorbed,*" the figures for 13 samples ranged between 1·70 and 4·47, the average being 2·50. Of these 13 samples, 8 were over two fields, and 5 were wholly or partly over three fields. All of them, excepting Nos. 9 and 131 ("oxygen absorbed" 2·08 and 4·47) and just possibly No. 360 ("oxygen absorbed" 2·40) remained sweet on incubation.

The average Ratio of Albuminoid Nitrogen to "oxygen absorbed" from permanganate in four hours is in nine effluents 1 : 14, after allowing for the nitrite present, the extremes being 1 : 7 and 1 : 18. On the whole this ratio is a tolerably even one, as is seen by a comparison of the respective curves.

Incubation.—Mr. Scudder's test, as judged by the difference in permanganate used up *at once*, before and after incubation, was more stringent here than the incubation test as judged by smell, only 5 samples out of 10, rigorously speaking, passing it. But the other 5 all nearly passed by it, so that in reality the two forms of incubation test agree very fairly here.*

The *Total Nitrogen* in 8 final and general effluents (6 of them over two fields and 2 partly over three fields) varied between 1·84 and 3·64, the average being 2·53. As already stated, this quantity was a fairly constant one (sample No. 126 is left out of account here).

The *Total Organic Nitrogen* in 8 samples of final and general effluent (omitting No. 4) ranged between 0·18 and 0·73, the average being 0·45. Without laying very great stress upon these figures, it is evident that the organic nitrogen is very appreciable when the comparatively small amount of total nitrogen is considered. But the organic matter of the effluents has been shown by the incubation test not to be of a very putrescent nature. Hence the relatively high figure for organic nitrogen is no doubt partly due to the fragments of weed found in the effluents (and the same applies to the albuminoid nitrogen). As only one or two estimations of organic nitrogen were done by the Kjeldahl method *without* reduction, no comparison can be made here between it and the method *with* reduction.

The individual variations between the *albuminoid* and the total *organic* nitrogen are considerable in these samples, but the averages of 8 final effluents make the total organic nearly two and a-half times the albuminoid.

Of 12 final second and third field effluents only three (Nos. 126, 129 and 132) contained any appreciable amount of nitrite, viz., 0·14, 0·14 and 0·11 parts *nitrous nitrogen*, four contained 0·01 to 0·05 parts and five contained none.

The quantity of *nitric nitrogen* in thirteen effluents varied between 0·0 and 1·73, with an average of 0·51; it only exceeded one part per 100,000 in the two samples,

* In those effluents (*i.e.*, in the greater part of them), where the amount of nitrous nitrogen left after incubation was not noted, it is assumed to be not greater than the nitrous nitrogen before incubation.

Nos. 3 and 353, out of a total of thirteen, while it approached one part in three other instances; otherwise it was very low, though it was only reduced absolutely to zero in three jointed or incubated samples—a further proof of the comparatively non-putrescent character of the organic matter left in the effluents. No. 127 contained no nitrate to begin with, and one would have expected it, from the analysis, to have gone bad on incubation, but it did not.

The ratio of oxidized to unoxidized nitrogen in eight samples (taking the unoxidized = 1) varied between 0 and 7·1, but there are too few analyses to draw any real conclusions here. Out of the eight analyses, several are inconclusive for one reason or another. Probably the "safety limit" ratio will be found to lie between 0·5 : 1 and 1 : 1.

The ratio of oxidized to albuminoid nitrogen (taking the albuminoid = 1) in 9 samples varied between 0 and 18·1. But here again the remark made in the preceding paragraph applies also. Probably the "safety limit" ratio is somewhere about 1·5 : 1 (if this should be correct, it is a very low ratio).

It has already been noted that the *chlorine* curve is a singularly uneven one, rising markedly in the warmer weather, no doubt from the increased evaporation then.

Conclusion.—The Leicester farm, depending as it does largely upon surface irrigation over a stiff clayey soil, treats a rather considerable volume of sewage of moderate nitrogenous strength but containing much oxidizable matter; the aggregate organic matter treated is of course not great (*cf.* Diagrams Nos. 3 and 4). The surface soil is from 6in. to 12in. deep; taking the number of particles in unit weight of the Nottingham surface soil (ignited) at 100, the number in the Leicester soil is 269, while the corresponding number in unit volume is 232. The effluents obtained, while not of a high class, are better as regards keeping property than the figures of analysis would lead one to expect. Taking them all over, they may be described as moderate. The sewage is no doubt a somewhat difficult one to treat, and the nitrifying area afforded by such a stiff soil and subsoil is necessarily small (relatively). As the slope of the farm, speaking generally, is all that could be wished for allowing the sewage to be treated over a number of plots of ground successively, the conditions in this respect are favourable. But on the other hand one must not forget that storm water up to twice the dry-weather-flow is treated, which must sometimes impose a considerable strain upon such heavy land (compare Beddington and South Norwood).

Percentage purification as calculated on the Albuminoid Nitrogen and "Oxygen Absorbed."

	Average.
(1) *Albuminoid Nitrogen*—5 chance samples of screened and settled sewage gave 0·66 to 1·70 - - -	1·11
3 sets of hourly samples of screened and settled sewage gave 0·97 to 1·44 -	1·19
9 Final effluents gave 0·07 to 0·35 - - - - - -	0·20
Percentage purification :—On chance samples - - -	82·0%
On hourly samples - - -	85·2%
(2) "*Oxygen absorbed*"—5 chance samples of screened and settled sewage gave 7·77 to 16·41 - - -	12·45
3 sets of hourly samples of sewage gave 20·28 to 24·83 - - - -	22·35
13 samples of effluent gave 1·70 to 4·47 - - - - -	2·50
Percentage purification :—On chance samples - - -	79·9%
On hourly samples - - -	87·7%

Comparison of the Total Nitrogen in the Sewages and Final Effluents.

	Average.
The average total nitrogen in the 3 sets of hourly samples of sewage was 7·32 to 9·16 - - - - - - - - -	8·12
The average total nitrogen in 8 final effluents was 1·84 to 3·64 -	2·53

The above figures show roughly that 30 per cent. of the original nitrogen of the sewage finds its way into the brook. But this is doubtless an over-estimate of the loss, for Mr. Kershaw says that there is practically no subsoil water on the farm, and a good many of the samples of final effluent were drawn during warm weather, when there must have been much evaporation from the ryegrass, etc.

Subsoil water.

Only one sample of this (No. 5) was examined. It was drawn with much difficulty by Mr. Kershaw "from a high portion of the farm which had never been actually sewaged itself, but which was within 50 yards (of sewaged ground). The sample was from a small sandy stratum in the boulder clay." Mr. Kershaw wrote further at the time:—"I cannot say with certainty that the sample is free from contamination from sewage, owing to the presence of a vein of sand."

The above sample arrived at the laboratory with a good deal of sediment, for it had to be drawn up in a tube, in small portions at a time, from the water-hole; but before analysis it had settled nearly clear. The analytical figures show that it it was a very pure water organically, with evidently no sewage contamination. The chlorine in it, though considerable, is almost exactly the same as that in the town's water (1·96 and 1·93). It was decidedly alkaline and contained much lime (present to a large extent as sulphate) in solution. The sample was no doubt partly aerated in the process of drawing. The Kjeldahl process *with* reduction, being an indirect process, is not adapted for the determination of organic nitrogen in such pure waters as this; the method *without* reduction gave a better result here.

Experiment to see how much sewage a given area of land would stand.
(*Diagrams Nos.* 25 *and* 26.)

Between September 10th and 27th, 1900, a small experiment was tried on the Leicester farm, with the object of seeing how soon the land would reach its limit of purifying power under a dose of sewage, beginning small, and increasing daily by a fixed moderate amount. For this purpose two plots were chosen, (*a*) an arable field of 6·5 acres and (*b*) a pasture field of 10·5 acres, these being pretty nearly the proportions of arable and pasture used in the ordinary course at Leicester. Mr. Kershaw says that "the arable field was stubble and there was very little grass on the pasture "field, the bullocks having been taken off that day. The dose of sewage was started "at about 200,000 gallons for the 17 acres per 24 hours," *i.e.*, 11,800 gallons (theoretically) per acre. It will be remembered that the usual quantity dealt with at Leicester at one time is 21,500 gallons per acre, so that at the commencement this dose was intended to be only about half the normal.

The appended diagram (Diagram No. 25) by Mr. Kershaw illustrates very clearly the difficulties attending an experiment of this nature, and also the difficulties which have to be overcome in applying sewage to any clay soil (compare his Notes on the Leicester samples). The comparatively small volume of sewage run on covered at first little more than one-third of the two fields; the effluent then reached the drains through cracks in the soil, and sample No. 137 could only be obtained after it had mixed with the effluent from another field. No. 138 was drawn before this mixing had taken place (265,000 gallons were now being run on); Mr. Kershaw noted here: "This effluent did not appear to be good," an opinion fully borne out by its analysis. We therefore thought it advisable to adopt at this stage the usual procedure at Leicester and to soak the land thoroughly, in order to swell it and fill up the cracks. So for the next three days, *i.e.*, until September 16th, 900,000 gallons per 24 hours were applied (*i.e.*, 2½ times the normal flow); by the latter date the whole of the two fields were being irrigated and some surface effluent was flowing from the arable field. At noon on the 16th, therefore, the flow of sewage was again cut down to 200,000 gallons for the entire area, *i.e.*, to the quantity originally applied on September 10th. Between September 16th and 27th the flow was increased by 3,000 gallons per acre per day. The last sample drawn (No. 148) was taken on the 27th, at which time 44,000 gallons per acre per day were being applied, rather more than double the normal quantity, which (the normal amount) was reached between September 19th and 20th. Unfortunately the sewaging did not even now (between September 16th and 27th) go on as uniformly as the above would indicate, for it will be seen, by reference to Mr. Kershaw's Notes,* that on September 21st the effluent from the arable field was removed to *another* portion of the pasture land, in order to give the part first sewaged a rest, as this was then becoming over-sewaged.

It seems hardly necessary to offer any detailed examination of the analyses of these effluents, but a few points may with advantage be noted, especially if they are read in connection with Mr. Kershaw's diagram and "Additional Notes on Samples,"* and with the Curves of the chemical results.

The samples were all two-field effluents, and, excepting the first drawn, No. 137, which was a filtration (!) effluent only, *they were all mixtures of surface and filtration effluent.* Of all the *thirteen* effluents only No. 144, and, no doubt, No. 143, with possibly No. 138, had a putrid smell at the date of analysis, the others having an earthy or slightly fishy odour. All those tested for reaction were alkaline, and the two tested for lime and sulphate in solution were found to contain much of these constituents.

In appearance, Nos. 137 and 138, drawn before the cracks in the ground had filled up, were grey and muddy, although No. 138 had no actual deposited sediment. The analysis of No. 137, though not good, shows that the sample kept sweet on incubation, being no doubt saved by some accumulated nitrate washed out of the fresh ground, and, perhaps, some nitrate in the effluent from the other field with which it was mixed. No. 138, though still containing a fair proportion of nitrate, went bad on incubation. At this stage the land received the large dose of sewage to swell the ground and fill up the cracks, and, by the time No. 139 was drawn, all

* Part IV. Engineering and Practical Report.

accumulated nitrate in the soil had evidently been used up or practically so, but the effluent kept sweet on incubation. In appearance this last sample showed a great improvement on Nos. 137 and 138, *i.e.*, it was brown and contained a small quantity of brownish flocculent matter, but was otherwise clear. No. 140 was much the same as No. 139, both in appearance and as regards analysis, but No. 141 was not so good, being slightly opalescent, giving an exceptionally high figure for "oxygen absorbed," and going bad on incubation. No. 142 was of more even composition and a better effluent than No. 141, though containing a good deal of flocculent matter. Nos. 143 and 144 were both bad, with much flocculent solid, and No. 144A was bad also, though better than the preceding two. It is worth noting here that this last sample was clear and brown, with only a little brownish sediment; a sign of the beneficial effect of the new piece of pasture land (*cf.* Mr. Kershaw's notes). No. 145 was also indifferent, though it had a clean smell when analysed; and No. 146 was distinctly bad on analysis, though with almost no flocculent suspended matter. No. 147 showed a marked improvement, contained 0·5 part nitric nitrogen and kept sweet upon incubation. It had apparently benefited by the rainfall at that date. No. 148 was very bad. At this point the sewaging was stopped. Very little rain fell until September 26–27, and even then the maximum was only 0·07 inches in 24 hours.

This experiment, though not affording a direct answer to the question—how much sewage an acre of the Leicester farm will purify—is in some ways instructive. First we have an effluent of indifferent appearance and not really purified, because of its having partly escaped into the drains through cracks in the soil, but kept non-putrescent in virtue of the accumulated nitrate which it has washed out. After that there is an improvement in purification up to No. 140, at which time it so happened that just about the normal flow for the Leicester farm was being treated. Then comes a gradual falling off, though with a few minor fluctuations, until sample No. 147 is reached, when the effluent is temporarily benefited by rain, only to relapse next day. In no case from No. 139 onwards is there any appreciable nitrate present in proportion to the total nitrogenous matter; that is to say, the purification effected is insufficient.

These few observations thus emphasize the point that most careful management is required on a clay sewage farm. Perhaps the most practical conclusion to be drawn from them is that any effluent from clay land which is partly made up of liquor that has escaped through cracks in the soil should be subsequently passed *for certain* over some uncracked ground, *e.g.*, ground in the condition that the above plots were in shortly after the soil had been swelled up with an excessive flow.

Water from the Anstey Brook, drawn both above and below the Leicester farm effluent outfall. (*Diagram No.* 27.)

In the Engineering Report* Mr. Kershaw speaks favourably of the condition of the Anstey Brook at the time of his visits—the brook into which the effluent from the Leicester farm flows (as well as the effluent from another small farm a little lower down).

Six samples from this brook were examined, three (Nos. 127B, 130A and 133) from above the effluent outfall, and three (Nos. 6, 134 and 135) from below it; but all were from above the effluent outfall of the other farm. Nos. 127B and 130A were jointed for a week before being analysed, and duplicates of Nos. 133 and 135 were also partially examined after being jointed for some time. Excepting No. 6, drawn in November, all the samples were taken in August and September 1900.

The above samples were either clear or opalescent, with small but appreciable amounts of flocculent matter in suspension. They were alkaline, had an earthy or slightly fishy-earthy smell, and contained much lime and much sulphate in solution.

No. 130A (*above* outfall) maintained its aeration fairly well, after being jointed for a week, which was satisfactory, especially as it was drawn when the brook was low.

No. 127B (*above*) had its dissolved oxygen nearly exhausted after being jointed for the same length of time in warm weather; this is of course not satisfactory for a brook water, but the stream was noted by Mr. Kershaw as very low when this sample was taken.

* Part IV. Engineering and Practical Report.

No. 133 (*above*) was very fair. It was drawn at a time when the brook had about its normal volume of water. After being jointed for ten days in the month of September it had lost very little of its dissolved oxygen, a severe test. Nos. 134 and 135 are both comparable with No. 133, having been drawn on the same day in order to furnish as nearly as possible comparative samples from above and below the effluent outfall. No. 134 (*below*), though still well aerated when analysed, contained relatively much oxidizable matter, but then it was drawn only 20 yards below the effluent outfall. No. 135, taken 160 yards lower down the stream than 134, was appreciably better than the latter and was also well aerated. After being jointed and kept for a week, however, its dissolved oxygen was reduced from 7·5 to 1·6 c.c. per litre, the nitrate being of course increased.

No. 6, the November sample taken probably about 15 yards below the effluent outfall, was only moderate, though well aerated, the "oxygen absorbed" figure being distinctly high for a brook water. Mr. Kershaw notes it as being rather turbid at the time of drawing.

The various curves, especially those for chlorine, "oxygen absorbed" and total nitrogen, show very clearly the effect of the inflow of effluent into the brook and require no elucidation.

The Anstey Brook may therefore be regarded as having been, from a chemical point of view, in a fairly satisfactory condition (for a non-drinking water stream) at the time of Mr. Kershaw's visits to Leicester, if we take the relatively small dilution of effluent by brook water into account.

LEICESTER SEWAGE FARM.

TABLES OF ANALYSIS.

INDEX.

	PAGE.
Hourly Sewage Samples, Nos. 469, 470, 471	141
Sewages and Effluents, Nos. 1, 2, 3, 4, 7, 8, 9	142–143
" " Nos 124, 125, 126	144
" " 127, 127A, 128, 128A, 129	145
Effluents, Nos. 130, 131, 132, 352	146
" Nos. 352, 353, 360, 364	147
Special Experiment :—	
Sewage and Effluents, Nos. 136, 137, 138, 139, 140, 141	148–149
Effluents, Nos. 142, 143, 144, 144A, 145, 146, 147, 148	150–151
Subsoil Water, No. 5	152
Brook Water above and below effluent outfall, Nos. 6, 127B, 130A	152
" " (including one effluent), Nos. 132, 133, 134, 135	153

LEICESTER SEWAGE FARM, 1902.

Hourly Sewage Samples drawn in Equal Quantities per hour.

No. of Sample	469	470	471
Nature of Sample	Screened and Settled Sewage 24 hours' sample.	Screened and Settled Sewage 24 hours' sample.	Screened and Settled Sewage. 24 hours' sample.
Rainfall while sample was being drawn*	0.00″	0·00″	0·00″
Drawn	From Monday, 10th February 1902, 12.30 noon, to 11th February, 11.30 a.m.	From Tuesday, 11th February 1902, 12.30 noon, to 12th February, 11.30 a.m.	From Wednesday, 12th February 1902, 12.30 noon, to 13th February, 11.30 a.m.
Analysed	12th February 1902	13th February 1902	14th February 1902
Parts per 100,000, *by weight.*			
Ammoniacal nitrogen	6·14	4·83	5·20
Albuminoid "	1·44	0·97	1·17
Nitrous "	None.	Doubtful trace.	None.
Nitric "	0·49	0·39	0·28
Total nitrogen by Kjeldahl, *with* reduction	9·16	7·32	7·88
Blank	(0·45 in 7·14)	(0·45 in 5·80)	(0·45 in 6·21)
"X" Nitrogen	1·09	1·13	1·23
Organic nitrogen by Kjeldahl, *with* reduction	2·53	2·10	2·40
Oxygen absorbed from permanganate at 26·7° C. (80° F.) *at once*	8·42	7·49	8·63
" " " *after four hours*	24·83	20·28	21·94
Chlorine	13·80	12·50	13·84
Total solids (gravimetrically)	159·2 { 65·4 volatile, 93·8 non-volatile	149·8 { 59·0 volatile, 90·8 non-volatile	151·6 { 58·2 volatile, 93·4 non-volatile
Solids in suspension	34·8 { 29·2 volatile, 5·6 non-volatile	33·8 { 25·0 volatile, 8·8 non-volatile	33·6 { 22·2 volatile, 11·4 non-volatile
Solids in solution	124·4 { 36·2 volatile, 88·2 non-volatile	116·0 { 34·0 volatile, 82·0 non-volatile	118·0 { 36·0 volatile, 82·0 non-volatile
Cellulose (still containing fat), by extraction with alkali and acid alone (a)	12·12	12·80	11·80
Cellulose, by alkali, acid and ether (b)	6·56	——	5·80
Grit { from (a)	2·88	3·20	2·88
Grit { " (b)	2·80	——	2·80
Parts per 100,000, *by volume.*			
Solids by Centrifuge	261·0 (3 minutes)	168·0 (3 minutes)	160·0 (3 minutes)
Remarks	Turbid and brown, with very dark brown sediment. Smell like that of hippuric acid. A few pieces of fibre, but the solids otherwise fairly fine. Alkaline. General solids up to 0·36 mm., one large piece of wood fibre, 4·72 mm. long, the rest small. Hair up to 1·04 mm.	Turbid and brown, but with less dark brown sediment than No. 469. Solids fairly fine. Hippuric acid smell. Alkaline. General solids up to 0·3 mm. (one piece 1·4 mm.) Hair up to 1·04 mm.	Turbid and brown, with about the same amount of dark brown sediment as in No. 470. Solids finely divided. Faint sewage smell. Alkaline. General solids up to 0·36 mm. Hair up to 1·98 mm.

*There were three inches of snow on the ground at the time, but no thaw.

LEICESTER SEWAGE FARM, 1899–1900.

Sewage with Effluents.

No. of Sample	1	2	3	4
Nature of Sample	Screened and Settled Sewage.	Intermediate Effluent (over one arable field).	Final Effluent (*i.e.*, over one arable field and then two pasture fields).	Final Effluent from No. 1 Outfall (over two fields, arable and pasture).
Drawn	Wednesday, 8th November, 1899, 11.15 a.m. (after heavy rain).	Wednesday, 8th November, 1899, 12.30 noon.	Wednesday, 8th November, 1899, 3.0 p.m.	Tuesday, 14th November, 1899, 3.0 p.m.
Temperature of sample	12·7° C. (55° F.)	11·1° C. (52° F.)	9·4° C. (49° F.)	9·4° C. (49° F.)
Temperature of air	11·1° C. (52° F.)	11·1° C. (52° F.)	10·0° C. (50° F.)	10·0° C. (50° F.)
If jointed or incubated	——	——	——	——
Analysed	10th November, 1899.	11th November 1899.	10th November 1899.	15th November 1899.
Parts per 100,000 *by weight.*				
Ammoniacal nitrogen— (a) by direct Nesslerization	——	——	——	——
(b) by distillation	1·34	1·28	0·59	1·03
Albuminoid nitrogen	0·66	0·28	0·07	0·16
Nitrous ,,	None.	None.	0·04	0·02
Nitric ,,	Not done.	Lost (probably none present).	1·23	0·63
Total nitrogen by Kjeldahl, *with* reduction (after correction for nitrite).	2·90	1·73	2·04	2·39
Blank	(0·17 in 4·82)	(0·17 in 2·95)	(0·17 in 3·41)	(0·17 in 0·43)
Correction for nitrite	None.	None.	+ ·02	+ ·01
"X" Nitrogen	0·90	0·17	0·11	0·55 (?)
Organic nitrogen by Kjeldahl, *with* reduction.	1·56	0·45	0·18	0·71 (?)
Organic nitrogen by Kjeldahl, *without* reduction :— Taking ammonia by distillation	1·23	0·48	0·20	0·08
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once.*	2·96	1·15	0·77	0·55
,, ,, *after 4 hours*	10·77	2·84	1·77	1·70
Oxygen absorbed from permanganate by sample incubated for 5 days at 26·7° C. (80° F.); *at once.*	——	——	——	——
,, ,, *after 4 hours*	Lost.	3·03	1·47	Lost.
Smell after incubation	——	Strong sewage smell, black deposit.	No smell.	——
Chlorine	3·50, 3·52 (done different ways.)	5·17, 5·14 (done different ways.)	7·28	8·90
Gases; Parts per 1,000 *by volume.*				
Carbon dioxide (free)	——	16·59	18·13	25·13
Oxygen (boiled out)	——	0·49	5·23	5·73
Nitrogen	——	15·20	15·26	15·80
Remarks	This sewage contained much sediment. Strongly alkaline.	This sample was brownish, with considerable sediment. Distinct sewage smell. Much lime. Alkaline.	Distinctly yellow and opalescent. Contained a little grit and flocculent, solid. Earthy (or very slightly fishy?) smell. Alkaline. Much lime in solution.	Slightly opalescent, with a good deal of flocculent matter which looked like weed of some kind. Brownish yellow colour. Earthy smell. Decidedly alkaline. Much lime. Much sulphate.

LEICESTER SEWAGE FARM, 1899–1900.

Sewage with Effluents.

4 Duplicate Sample.	7 Settled Sewage.	8 Effluent off Arable Field No. 107 (*i.e.*, over one field).	9 Final Effluent off field No. 104 (*i.e.*, over two fields, arable and pasture).	9 Large Duplicate Sample.
—	Tuesday, 21st November, 1899, 12.0 noon.	Tuesday, 21st November, 1899, 1.30 p.m.	Tuesday, 21st November, 1899, 2.45 p.m.	—
—	14·4° C. (58° F.)	7·2° C. (45° F.)	6·6° C. (44° F.)	—
—	7·2° C. (45° F.)	7·2° C. (45° F.)	6·6° C. (44° F.)	—
Jointed 15th November, 1899. 30th November, 1899.	— 24th November, 1899.	— 23rd November, 1899.	— 22nd November, 1899.	Jointed 23rd November, 1899 6th March 1900.
—	Too turbid to read.	Only an approximate reading possible.	Only an approximate reading possible.	Turbid.
0·87	3·43	2·19	2·58*	2·80
0·25	1·29	0·42	0·15*	0·13
0·04	None.	None.	None.	None.
1·00	Not done.	0·08	None.	None.
2·47	4·78	3·47	2·92	2·88
(0·17 in 4·10)	(0·17 in 7·84)	(0·17 in 5·74)	(0·17 in 4·85)	(0·22 in 4·40)
+ ·02	None.	None.	None.	None.
0·31	0·06	0·78	0·19	None (–0·05)
0·58	1·35	1·20	0·34	0·13
0·08	—	None.	0·68	—
		Liquid turbid with "Nessler." Could not read accurately.	Difficult to read. Oxalate used.	
0·97	5·99	4·30	0·97	0·46
1·55	12·43	7·88	2·18	2·08
—	—	—	—	—
1·38 (4 days)	15·54	8·64	2·01	Not done.
No smell.	Sulphide smell. Black deposit.	Sulphide smell. Black deposit.	Only a musty smell.	—
—	10·06 (Evaporation). 10·08 Direct 10·00 Titration.	9·36 (Evaporation). 9·40 Direct Titration.	10·20 (Evaporation). 10·15 Direct 10· 0 Titration.	Not done.
33·86	—	—	40·11	44·09†
0·95	—	—	4·70	0·12
15·77	—	—	17·02	16·73
The weather had been mild for November. On November 30th there was a small bubble of gas (say 0·2 c.c.) at top of bottle, and a slight suction inwards on opening. Brownish colour. Earthy smell.	This sewage contained a copious brown sediment. The liquid was almost opaque.	This sample contained a slight brown sediment. Putrid smell. Alkaline.	Very slightly opalescent. Distinct brown colour. Earthy smell. A little brownish flocculent matter. Alkaline. Much lime. Much sulphate. No appreciable iron in solution. *Estimated November 23rd, after bottle had stood half empty overnight.	On opening there was a bubble of gas at top of bottle. No pressure. Very yellow but clear, with some deposited sediment. Strong sulphuretted hydrogen odour, *i.e.*, putrid. Alkaline. †Here the increase in the carbon dioxide is approximately equal to the decrease in the oxygen.

LEICESTER SEWAGE FARM, 1900.

Sewage with Effluents.

No. of Sample	124		125		126		126	
Nature of Sample	Screened and Settled Sewage.		First Field Effluent (over ploughed land).		Final Effluent off Pasture Land (*i.e.*, over two fields).		Large Duplicate Bottle.	
Drawn	Tues., 21st Aug. 1900, 12.30 noon.		Tues., 21st Aug. 1900, 1.30 p.m.		Tues., 21st Aug. 1900, 3.15 p.m.		—	
Temperature of sample	17·80° C. (64° F.)		21·1° C. (70° F.)		20° C. (68° F.)		—	
Temperature of air	20·6° C. (69° F.)		22·2° C. (72° F.)		21·7° C. (71° F.)		—	
If jointed or incubated	—		—		—		Jointed 22nd August 1900.	
Analysed	22nd August 1900.		23rd August 1900.		22nd August 1900.		3rd September 1900.	
Parts per 100,000, *by weight.*	Same bottle. (A)	(B)	Separate bottles. (A)	(B)	Separate bottles. (A)	(B)	Same bottle presumably. (A)	(B)
Ammoniacal nitrogen (by distillation)	4·84	4·96	3·53	3·50	1·21	1·26	1·15	1·19
Albuminoid "	1·09	0·86	*0·74	0·43	0·24	0·23	0·22	0·19
Nitrous "	None.	None.	Probably None.	None.	0·15	0·15	0·14	0·14
Nitric "	Not done.	Not done.	Not done.	Not done.	0·80	0·70	0·84	0·79
Total nitrogen by Kjeldahl, *with* reduction (after correction for nitrite).	6·77	6·78	4·59	4·52	2·72	—	2·43	2·36
Blank	(·24 in 5·04 ; ·13 in 5·91)		(·14 in 6·63 ; ·13 in 6·47)		(·14 in 3·90)	—	(·14 in 3·48; ·13 in 4·34)	
Correction for nitrite	None.	None.	None.	None.	+ ·07	—	+ ·07	+ ·07
"X" nitrogen	0·84	0·96	0·32	0·59	0·32	—	0·08	0·05
Organic nitrogen by Kjeldahl, *with* reduction.	1·93	1·82	1·06	1·02	0·56	—	0·30	0·26
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once.*	7·35	8·33	5·00	5·15	0·83	1·10	0·78	0·58
" " " *after four hours.*	15·01	14·77	9·04	8·79	3·08	2·89	2·78	2·88
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.) *at once*	—		5·62	5·94	0·96	1·09	—	1·22
" " " *after four hours.*	—		9·98	9·96	Lost.	2·52	—	2·66
Smell after incubation	—		Blackened, very putrid, slight sulphide smell.		Sweet (?)	Not noted.	—	Earthy.
Chlorine	12·24	11·64	12·06	—	10·90	11·15	—	
Parts per 100,000, *by volume.*								
Solids by centrifuge	—		—		—		—	
Gases ; Parts per 1,000, *by volume*								
Oxygen (by cuprous chloride), when sample was analysed*.	—		—		About 1·0		Probably not noted.	
Remarks	Considerable dark brown sediment. Faint sewage smell. Strongly alkaline.		This sample was strongly putrid when the bottle was opened. Very turbid and brown. Small amount of dark brown deposit. Alkaline.		This sample was slightly opalescent and of a rather deep brown colour. There was one small piece of weed in it. Seaweed smell. Strongly alkaline.		Between August 22nd and September 3rd the weather was moderately warm only.	

* *Note.*—As the Leicester effluents were yellow to brown in colour, those figures for oxygen obtained with cuprous chloride are almost certainly too low, and must be taken with great reserve.

* *Note.* — Judging from the other figures, this estimation is probably incorrect. The lower figure is taken.

LEICESTER SEWAGE FARM, 1900.

Sewage with Effluents.

127	127a	128	128a	129	129
FINAL EFFLUENT after Plough and then Pasture (two Fields).	FIRST FIELD EFFLUENT (over ploughed land).	SCREENED AND SETTLED SEWAGE.	FIRST FIELD EFFLUENT (off ploughed land).	FINAL EFFLUENT over Plough and Pasture (two Fields).	DUPLICATE.
Ved., 22nd Aug. 1900, 2.0 p.m.	Mon., 22nd Aug. 1900, 12.0 noon.	Mon., 27th Aug. 1900, 11.15 a.m.	Mon., 27th Aug. 1900, 12.15 noon.	Mon., 27th Aug. 1900, 2.0 p.m.	—
15·6° C. (60° F.)	21·7° C. (71° F.)	15·6° C. (60° F.)	17·2° C. (63° F.)	16·7° C. (62° F.)	—
16·7° C. (62° F.)	18·9° C. (66° F.)	15·6° C. (60° F.)	17·8° C. (64° F.)	16·1° C. (61° F.)	—
—	—	—	—	—	Jointed, 28th Aug. 1900.
23rd Aug. 1900.	24th Aug. 1900.	28th Aug. 1900.	29th Aug. 1900.	28th Aug. 1900.	7th Sept. 1900.
Separate bottles. (A) (B)	Separate bottles. (A) (B)	Same bottle. (A) (B)	Separate bottles. (A) (B)	Separate bottles. (A) (B)	
1·96 1·76	3·29 3·28	3·62 3·56	3·06 2·89	2·20 2·08	—
0·30 0·22	0·37 0·37	0·94 0·92	0·44 0·30	*0·22 0·13	—
0·04 0·05	None. None.	None. None.	None. None.	0·13 0·14	0·17 Nitrite and nitrate nitrogen.
None. None.	Not done. Not done.	Not done. Not done.	Not done. Not done.	None. None	
2·55 2·52	4·18 4·11	4·93 4·61	{3·54, 3·51} 3·23	2·61 —	—
·14 in 3·71; ·13 in 3·62)	(·24 in 6·14; ·13 in 5·90)	(·24 in 3·72; ·13 in 3·36)	(·14 in 3·89 & in 2·62) (·13 in 5·80)	(·14 in 4·63) —	—
+ ·02 + ·03	None. None.	None. None.	None. None.	+ ·07 —	—
0·25 0·49	0·52 0·46	0·37 0·13	0·03 0·14	0·06 —	—
0·55 0·71	0·89 0·83	1·31 1·05	0·47 0·44	0·28 —	—
0·70 1·04	5·31 5·79	2·32 2·89	1·23 1·16	0·70 0·58	—
2·97 2·86	9·06 9·22	7·86 7·68	3·39 3·26	2·27 2·17	—
				3 days 6 days 5 days	
0·72 1·30	5·76 5·76	Not done. Not done.	1·64 2·12	0·59 0·58 0·41	—
3·03 3·01	9·95 9·75	,, ,,	3·62 3·80	2·16 2·01 2·03	—
Earthy. —	Blackened, putrid, sulphide smell.	—	Putrid. sulphide smell.	Slight earthy. Slight earthy. —	—
(*) 11·66 (*) 13·10	13·26 12·96	7·98 7·72	8·28 8·40	10·60 10·60	—
—	—	—	—	—	—
Probably none.	—	—	—	1·2 —	A trace only, considerably less than 1 c.c.
Liquid clear and very brown. It contained one aggregated piece of suspended matter, about the size of a hazel nut, which looked like weed and fibre, &c. Slight earthy, or perhaps seaweed smell. Alkaline. Another bottle was jointed on August 23rd, and was opened on September 4th. It had only a clean earthy smell. *This is noteworthy, when considered in reference to the above analyses.* (*) Cannot account for this discrepancy.	In this sample there was a small amount of dark brown deposit. The liquid was brown and turbid, and with a strong putrid odour. Alkaline.	Moderate amount of brown and greyish deposit. Putrid smell. Alkaline.	This sample had a strong sewage smell. It was brownish and opalescent, with a small amount of brownish deposit. Alkaline.	Slightly yellow or brown tint. In one bottle a few greenish particles; in the other a very small amount of light coloured sediment, which looked like fragments of roots and plants. Earthy smell. * Judging from the other figures, this is probably overestimated. The lower figure is taken.	The weather was, I think, rather warm between August 28th and September 7th.

LEICESTER SEWAGE FARM, 1900-1.

Effluents.

No. of Sample	130		131		132		132	352
Nature of Sample	Final Effluent off Plough and Pasture (two Fields).		Final Effluent off Fallow and Pasture (two Fields).		General Effluent in equal proportions from each Outfall.		Large Duplicate	Final or Third Effluent, *i.e.*, over three Fields.
Drawn	Wednesday, 29th Aug. 1900, 11.45 a.m.		Thursday 30th Aug. 1900, 11.30 a.m.		Monday, 3rd Sept. 1900, 11.45 a.m.		——	Monday, 30th Sept. 1901, 1.0 p.m.
Temperature of sample	14·4° C. (58° F.)		17·8° C. (64° F.)		15·0° C. (59° F.)		——	15·0° C. (59° F.)
Temperature of air	16·1° C. (61° F.)		18·9° C. (66° F.)		17·2° C. (63° F.)		——	19·4° C. (67° F.)
If jointed or incubated	——		——		——		Jointed, 4th Sept. 1900.	——
Analysed	30th August 1900		31st August 1900		4th Sept. 1900.		17th Sept. 1900.	2nd October 1901
Parts per 100,000, *by weight.*	Same bottle. (A)	(B)	Same bottle. (A)	(B)	(A)	(B)		
Ammoniacal nitrogen (by distillation)	1·27	1·28	2·92	2·69	1·33	Lost.	1·48	——
Albuminoid nitrogen	*0·28	0·14	0·36	0·34	0·31	Lost.	0·25	——
Nitrous "	0·01	0·01	None.	None.	——	0·11	0·10	None.
Nitric "	0·25	0·13	Lost. (Take 0·21)	0·21	——	0·36	0·65 {Probably wrong}	0·51
Total nitrogen by Kjeldahl, *with* reduction, after correction for nitrite.	1·85	1·83	3·70	3·57	——	2·29	2·26	——
Blank	(·14 in 2·74)	(·13 in 3·29)	(·14 in 5·37)	(·13 in 6·39)	——	(·13 in 3·26)	(·17 in 3·26)	——
Correction for nitrite	None.	None.	None.	None.	——	+ ·06	+ ·05	——
"X" nitrogen	0·04	0·27	0·42	0·33	——	0·18	?	——
Organic nitrogen by Kjeldahl, *with* reduction.	0·32	0·41	0·78	0·68	——	0·49	?	——
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once.*	0·62	——	1·91	2·24	——	0·79	0·74	0·51
" " " *after four hours.*	2·40	2·68	4·47	4·63 ($4\frac{2}{3}$ hrs.)	——	2·37	1·91	2·33
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once*	0·60	0·63	2·18	2·25	——	0·60	Not done.	0·45
" " " *after four hours*	1·84	2·22	4·75	4·43	——	2·22	"	1·74
Smell after incubation	Sweet; faint sea-weed smell.		Blackened. Sulphide.	Fairly strong putrid smell.	——	Slight earthy.	——	Sweet; about 0·03 nitrite nitrogen.
Chlorine	11·62	11·70	12·80	12·86	——	12·24	12·40	——
Parts per 1,000, *by volume.*								
Solids by centrifuge	——		——		——		——	25·0
Gases; Parts per 1,000, *by volume.*								
Oxygen (by cuprous chloride), when sample was analysed.	Probably a trace. Liquid very brown.		Probably none. Very brown.		1·0 to 1·5 (Very green)		Trace.	None.
Remarks	Liquid rather deep brown in colour. Several large greenish-brown flocculi. Faint sea-weed smell. Alkaline. *Judging from the other figures, this estimation is probably wrong. The lower figure is taken.		More or less turbid. One large piece of brown flocculent matter. Faintly alkaline.		Liquid clear but slightly yellow. Contained a little light-coloured matter in suspension. Earthy smell. Alkaline.		Liquid clear but slightly yellow. All the sediment, which was light brown in colour, had settled to the bottom. Slight earthy smell. Alkaline.	Clear brown liquid. Fair amount of brown sediment. Slight fishy smell. Alkaline.

LEICESTER SEWAGE FARM, 1900-1.

Effluents.

352	353	353	360	360	364	364
ALL DUPLICATE,	GENERAL EFFLUENT, marked "A."	SMALL DUPLICATE,	FINAL OR THIRD EFFLUENT from Rye Grass *i.e.*, over three Fields.	SMALL DUPLICATE,	GENERAL EFFLUENT marked "C."	SMALL DUPLICATE.
—	Tuesday, 1st Oct. 1901, 11.30 a.m.	—	Wednesday, 2nd Oct. 1901, 1.0 p.m.	—	Thursday, 3rd Oct. 1901, 12.45 noon.	—
—	14·4° C. (58° F.)	—	16·7° C. (62° F.)	—	16·1° C. (61° F.)	—
—	18·3° C. (65° F.)	—	17·2° C. (63° F.)	—	16·1° C. (61° F.)	—
inted and incu-bated 1st Oct. 901. th October 1901.	— 3rd October 1901.	Jointed and incu-bated 3rd Oct. 1901. 15th October 1901.	— 3rd October 1901.	Jointed and incu-bated 3rd Oct. 1901. 15th October 1901.	— 4th October 1901.	Jointed and incu-bated 4th Oct. 1901. 23rd October 1901.
—	—	—	—	—	—	—
—	—	—	—	—	—	—
None.	1·73	0·05	None.	None.	None.	None, or merest trace.
0·56		1·86	0·21	0·03	0·30	0·02
—	—	—	—	—	—	—
—	—	—	—	—	—	—
—	—	—	—	—	—	—
—	—	—	—	—	—	—
—	—	—	—	—	—	—
—	0·63	—	0·49	—	0·68	—
—	2·28	—	2·40	—	2·29	—
—	0·70	—	0·55	—	0·53 } 6 days.	—
—	2·29	—	2·14	—	3·29 } 6 days.	—
—	Sweet; about 0·06 nitrite nitrogen.	—	Sweet; no nitrite.	—	Sweet; about 0·03 nitrite nitrogen.	—
—	—	—	—	—	—	—
—	19·0	—	40·0	—	25·0	—
None.	Probable trace (masked by colour).	—	Probable trace (masked by brown colour).	—	1 c.c. approx. (but the colour was very green).	None.
fter incubation, this was a rather brown, slightly-turbid liquid. Fair amount of light brown sediment. Alkaline.	Clear brown liquid. Not much sediment (brown). No smell. Alkaline.	After incubation, clear brown liquid. A very little light brown sediment. No smell. Alkaline.	Brown, slightly turbid liquid, with a considerable amount of deep brown sediment. Alkaline. Clean smell.	After incubation, clear brown liquid. Not much light brown sediment. Suspicious though not putrid smell. Alkaline.	Liquid brown and clear. Fair amount of reddish-brown sediment. Clean smell. Alkaline.	After incubation, yellow liquid, with one flock of grey-brown sediment. Strong earthy smell. Alkaline.
			This sample is evidently on the border line		This is another interesting case.	

LEICESTER SEWAGE FARM, 1900.

Special Experiment.

No. of Sample	136	137	137	137
Nature of Sample	Screened and Settled Sewage.	Final Effluent over Arable and Pasture (two Fields).	Large Duplicate.	Small Duplicate.
Drawn	Monday, 10th Sept. 1900. 12.0 noon	Tuesday, 11th Sept. 1900. 1.0 p.m.	—	—
Temperature of sample	17·2° C. (63° F.)	15·6° C. (60° F.)	—	—
Temperature of air	18·3° C. (65° F.)	15·0° C. (59° F.)	—	—
If jointed or incubated	—	—	Jointed, 12th Sept. 1900.	Jointed, 12th Sept. Incubated, 20th Sept. 1900.
Analysed	12th Sept. 1900.	12th Sept. 1900.	24th Sept. 1900.	25th Sept. 1900.
Parts per 100,000, *by weight.*				
Ammoniacal nitrogen (by distillation)	6·20	0·63	0·71	0·86
Albuminoid "	1·70	0·27	0·21	0·21
Nitrous "	None.	0·20	Trace.	Trace.
Nitric "	Not done.	1·69	1·29	0·97
Total nitrogen by Kjeldahl, *with* reduction (after correction for nitrite).	8·61	3·14	2·33	—
Blank	(0·17 in 6·20)	(0·17 in 4·39)	(0·17 in 3·43)	—
Correction for nitrite	None.	+0·12	None.	—
"X" nitrogen	0·71	0·35	0·11	—
Organic nitrogen by Kjeldahl, *with* reduction.	2·41	0·62	0·32	—
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once.*	5·62	1·19	0·64	0·44
" " " *after four hours.*	16·41	3·32	2·18	1·73
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once*	Not done.	0·16	7 days. 0·62	—
" " " *after four hours.*	Not done.	1·36	7 days. 1·94 (4½ hours.)	—
Smell after incubation	—	Not noted. Presumably sweet.	Quite sweet.	Sweet.
Chlorine	7·14	10·34	10·20	Not done.
Gases; Parts per 1,000, *by volume.*				
Carbon dioxide (free)	—	28·84	—	—
Oxygen (boiled out)	—	0·05	Not done.	—
Oxygen (by cuprous chloride)*: When sample was analysed	—	1·0 to 1·5 (Very difficult to read.)	—	—
Nitrogen	—	14·39	—	—
Remarks	This sample contained a good deal of aggregated sediment, which was very hard to break up. The sampling was therefore not so good as usual.	This effluent was grey and muddy. Land used after a long rest, and not working properly yet. Clean earthy smell. Very much lime. Much sulphate. Decidedly alkaline.	Liquid now slightly opalescent, the sediment having settled. Sediment was greyish-brown; not a great deal of it. At first the smell was taken as putrid, but this must have been due to rubber of joint. When the liquid was shaken a little, it had a very strong fishy smell.	Liquid now clear. Very little sediment. Sweet smell. Alkaline.

* As those effluents were yellow to brown in colour, the oxygen figures given by the cuprous chloride method will be too low.

LEICESTER SEWAGE FARM, 1900.

Special Experiment.

138 NAL EFFLUENT, er same land as No. 137.	138 SMALL DUPLICATE.	139 FINAL EFFLUENT over same land.	140 FINAL EFFLUENT over same land.	140 SMALL DUPLICATE.	141 FINAL EFFLUENT over same land.	141 LARGE DUPLICATE.
Wednesday, 2th Sept., 1900. 12.0 noon.	—	Monday, 17th Sept. 1900. 12.0 noon.	Tuesday, 18th Sept. 1900. 12.0 noon.	—	Wednesday, 19th Sept. 1900. 12.0 noon.	—
7·2° C. (63° F.)	—	16·7° C. (62° F.)	16·7° C. (62° F.)	—	20·6° C. (69° F.)	—
2·8° C. (73° F.)	—	18·3° C. (65° F.)	17·2° C. (63° F.)	—	20·6° C. (69° F.)	—
—	Jointed, 13th Sept. 1900. Incubated, 25th Sept. 1900.	—	—	Jointed, 19th Sept. 1900, and kept evidently at laboratory temperature.	—	Joi ted, 20th Sept. 1900. Opened 24th, Oct. and let in 2 to 3 c.c. air; jointed again. Repeated this on 26th Oct.
3th Sept. 1900.	4th or 5th Oct. 1900.	18th Sept. 1900	19th Sept. 1900.	1st October 1900.	20th Sept. 1900.	14th Nov. 1900.
0·84	1·12	1·48	1·60	1·50	1·13	1·26
0·32	0·18	0·14	0·17	0·16	0·21	0·17
0·20	Trace.	0·06	0·04	0·04	0·06	None.
1·00	None.	0·20	0·04	0·04	0·26	None.
2·58	—	2·01	1·88	Not done.	1·71	With sugar. 1·57 Without. 1·60
(0·17 in 4·47)	—	(0·17 in 3·64)	(0·17 in 3·42)	"	(0·17 in 2·52)	(0·12 in 2·36 ; 0·12 in 2·41)
+0·12	—	+ ·03	+ ·02	"	+ ·03	None.
0·22	—	0·13	0·03	"	0·05	0·14
0·54	—	0·27	0·20	"	0·26	0·31
1·11	0·75	*0·19	0·64	0·82	0·79	0·59
3·64	—	3·00	2·85	2·76	$4\frac{1}{3}$ hours {5·93} (?)	2·98
0·48	—	1·02	0·91	—	1·05	0·56
2·53	—	2·80	2·93	—	†3·20	2·93 {$4\frac{1}{2}$ hours
trid. Fairly strong sulphide smell.	Putrid.	Earthy.	Clean earthy.	—	Putrid.	Distinctly putrid.
10·96	—	10·64	10·90	—	Not done.	Not done.
—	—	—	—	—	‡36·45	—
—	—	—	—	—	0·22	—
actically unaërated. Got a turbid yellow-green, which was not comparable with standard.	—	About 1·0 (not more) (Dark green obtained was not comparable with standard).	Trace. (*i.e.*, less than 1·0)	—	(Unaërated. Gave only a pale yellow green.)	Not examined.
—	—	—	—	—	14·09	—
is sample was urbid and grey, ut with no leposited sediment. Possibly faint sewage mell. Alkaline.	When this bottle was opened, the liquid smelt putrid, though not very badly so ; but it was analysed on account of the original sample having contained 1·0 part nitric nitrogen.	This sample was distinctly brown and contained a small amount of brownish flocculent matter, otherwise it was clear. Earthy smell. Alkaline.	This sample was nearly clear, *i.e.*, only slightly opalescent, though of a distinct brown tint. It contained only a little red-brown flocculent matter. Fishy-earthy smell. Alkaline.	Sweet earthy smell. Alkaline. (It was fairly warm autumn weather between Sept. 19th and Oct. 1st.)	Pale brownish yellow in colour and slightly opalescent. Faint sea-weed (rather peculiar) smell. Alkaline. Very much lime. Much sulphate. Trace of iron.	Dark yellow, with a moderate amount of brown flocculent sediment. Clean smell. This latter shows that the decomposition had not proceeded far in this time at the laboratory temperature.

* Very low figure.

The above is an interesting analysis, as there was so little nitrate to draw upon.

† This portion was slightly aërated by mistake before incubating.

‡ This is nearly, but not quite, all the free carbonic acid.

LEICESTER SEWAGE FARM, 1900.

Special Experiment—*continued.*

No. of Sample	142	142	143	144
Nature of Sample	Final Effluent over same land.	Small Duplicate.	Final Effluent over same land.	Final Effluent over same land.
Drawn	Thursday, 20th Sept. 1900, 12.0 noon.	—	Frid., 21st Sept. 1900, 12.0 noon.	Sat., 22nd Sept. 1900, 12.0 noon.
Temperature of sample	14·4° C. (58° F.)	—	16·1° C. (61° F.)	17·2° C. (63° F.)
Temperature of air	18·9° C. (66° F.)	—	22·2° C. (72° F.)	22·2° C. (72° F.)
If jointed or incubated	—	Jointed and incubated 21st Sept. 1900.	Jointed 22nd Sept. 1900.	—
Analysed	22nd Sept. 1900	28th Sept. 1900.	Opened 24th Oct. 900.	Opened 24th Sept. 1900.
Parts per 100,000 *by weight.*				
Ammoniacal nitrogen (by distillation)	1·37	1·30	—	—
Albuminoid "	0·19	0·16	—	—
Nitrous "	0·07	0·06	—	—
Nitric "	0·11	0·06	—	—
Total nitrogen by Kjeldahl, *with* reduction.	1·94	Not done.	—	—
Blank	(0·17 in 2·83)	—	—	—
Correction for nitrite	+0·04	—	—	—
"X" Nitrogen	0·20	—	—	—
Organic Nitrogen by Kjedlahl, *with* reduction.	0·39	—	—	—
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once.*	0·80	0·93	—	—
" " " *after four hours.*	2·93	2·82	—	—
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once*	0·59	—	—	—
" " " *after four hours.*	2·70	—	—	—
Smell after incubation	Pleasant earthy.	Pleasant earthy.	—	—
Chlorine	10·60	Not done.	—	—
Gases; Parts per 1,000 *by volume.*				
Oxygen (by cuprous chloride):— When sample was analysed	Unaerated. Got practically no green.	—	—	—
Remarks	Distinctly brown (more so than yesterday's sample) and with a good deal of flocculent matter in it. Fishy-earthy smell. Alkaline.	—	When opened this bottle contained much black sediment, and the sample was exceedingly putrid. Very bad effluent. Not analysed.	This effluent was already distinctly putrid; the flocculent matter (of which there was not very much) was greyish-brown. Not analysed.

LEICESTER SEWAGE FARM, 1900.

Special Experiment—*continued.*

144a	145	146	146	147	148
FINAL EFFLUENT (small bottle) over same land.	FINAL EFFLUENT over same land.	FINAL EFFLUENT over same land.	DUPLICATE.	FINAL EFFLUENT over same land.	FINAL EFFLUENT over same land.
Sun., 23rd Sept. 1900, 12.0 noon.	Mon., 24th Sept. 1900, 12.0 noon.	Tues., 25th Sept. 1900, 12.0 noon.	—	Wed., 26th Sept. 1900, 12.0 noon.	Thurs., 27th Sept. 1900, 12.0 noon.
17·2° C. (63° F.)	13·9° C. (57° F.)	16·1° C. (61° F.)	—	13·3° C. (56° F.)	14·4° C. (58° F.)
18·3° C. (75° F.)	15·6° C (60° F.)	18·3° C. (65° F.)	—	15·0° C. (59° F.)	17·8° C. (64° F.)
Jointed and incubated 25th Sept. 1900.	—	—	Jointed 26th Sept. 1900.	—	—
12th Oct. 1900.	26th Sept. 1900.	26th Sept. 1900.	Opened 24th Oct. 1900.	27th Sept. 1900.	28th Sept. 1900.
				Unfiltered. Filtered	
1·47	2·37	2·20	—	1·02 1·06	1·60
0·21	0·24	0·38	—	0·23 0·18	0·30
None.	None.	None.	—	0·05 —	None.
None.	0·02	0·14	—	0.51 —	None.
—	2·84	2·87	—	2·01 —	2·11
—	(0·17 in 5·13)	(0·17 in 5·20)	—	(0·17 in 3·64)	(0·17 in 3·86)
—	None.	None.	—	+ ·03 —	None.
—	0·21	0·15	—	0·20 —	0·21
—	0·45	0·53	—	0·43 —	0·51
0·72	1·29	2·53	—	1·05 1·02	0·86
—	3·54	5·49	—	3·07 2·95	3·63
—	1·17	2·68	—	0·66 Not incubated.	1·44
—	3·51	5·50	—	2·80	3·90
Putrid.	Putrid.	Very putrid. Black sediment.	—	Earthy.	Distinctly putrid.
—	10·60	11·60	—	12·36	12·50
—	Unaerated.	None.	—	About 1·0 (Comparison difficult.)	None.
This incubated sample was clear and decidedly brown, with only a little sediment (brownish). It had a doubtful smell.	This sample was slightly opalescent with a small amount of dark-brown flocculent matter. Good clean smell.	Yellowish-brown and distinctly opalescent, but with almost no flocculent matter. Fishy-earthy smell (a trifle suspicious).	When opened this was strongly putrid, and with a black deposit. Not analysed.	This sample looked fairly good. It was yellowish-brown, slightly opalescent, aud with hundreds of very minute worms swimming about in it. Smell. slightly fishy-earthy.	Pale brown-yellow as usual. Slightly opalescent. Small quantity of red-brown flocculent matter, probably partly bodies of worms. Not so many live worms as in yesterday's sample. Clean, slightly fishy-earthy smell. When drawn, this sample looked better (than the preceding one), and there was more oxygen in it.

LEICESTER SEWAGE FARM, 1899–1900.

Subsoil Water; Brook Water, alone and admixed with Effluent.

No. of Sample	5	6	127b	130a
Nature of Sample	Subsoil Water at depth of 7 ft. 6 in. Drawn by a Syphon.	Brook Water. 80 yards below Effluent Outfall.	Brook Water above Effluent Outfall.	Brook Water above Effluent Outfall.
Drawn	Wednesday, 15th November, 1899, 1.0 p.m.	Monday, 20th Nov., 1899, 2.30 p.m.	Wed., 22nd August 1900, 1.0 p.m.	Wed., 29th August 1900, 12.0 noon.
Temperature of sample	10·5° C. (51° F.)	9·4° C. (49° F.)	17·8° C. (64° F.)	14·4° C. (58° F.)
Temperature of air	9·4° C. (49° F.)	9·4° C. (49° F.)	16·1° C. (61° F.)	16·7° C. (62° F.)
If jointed or incubated	——	——	Jointed 23rd August, 1900.	Jointed 30th August 1900.
Analysed	17th November 1899.	21st November 1899.	29th August 1900.	7th Sept. 1900.
Parts per 100,000, *by weight.*			(A) (B)	
Ammoniacal nitrogen:				
(a) By direct Nesslerization	——	0·51	——	——
(b) By distillation	0·005	0·52	——	——
Albuminoid nitrogen	0·010	0·06	——	——
Nitrous "	None.	Trace.	0·17 0·17	0·20
Nitric "	0·040	0·46 (Probably wrong.)		
Total nitrogen by Kjeldahl, *with* reduction, after correction for nitrite	0·162	0·969	——	——
Blank	(0·17 in 0·43)	(0·17 in 1·73)	——	——
Correction for nitrite	None.	None.	——	——
"X" nitrogen	0·107	None (?) (−0·07)	——	——
Organic nitrogen by Kjeldahl, *with* reduction.	0·117 (?)	0·06 (?)	——	——
Organic nitrogen by Kjeldahl, *without* reduction:				
(a) Taking ammonia by direct Nesslerization.	——	0·18	——	——
(b) Taking ammonia by distillation.	0·081	0·17	——	——
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once.*	0·040	0·28	——	——
" " " *after four hours*	0·079	0·71	——	——
Oxygen absorbed from permanganate by sample incubated for five days at 26 7° C. (80° F.); *at once*	——	——	——	——
" " " *after four hours*	0·125	0·97	——	—
Smell after incubation	No smell.	Slight earthy smell.	——	——
Chlorine	1·96	3·80	——	——
Gases; Parts per 1,000, *by volume.*	Total carbon dioxide Nov. 17th 52·94; *Nov. 20th 135·02			
Carbon dioxide (free)		22·29	——	——
Oxygen (boiled out)	5·14 5·01	7·99	——	——
" (by cuprous chloride), when sample was analysed.	——	——	0·8	5·2
Nitrogen	17·16 16·22	17·15	——	——
Remarks	When sample arrived, there was a good deal of sediment in it. Nearly clear when analysed. Decidedly alkaline. Much *lime* present, to a large extent as *sulphate*. No smell. The sample was no doubt aerated in the process of drawing. * This portion had been standing in a full 250 c.c. flask.	Sample opalescent, with yellowish tinge. A little brownish and white flocculent matter. Strongly alkaline. Much lime. Much sulphate. Earthy smell.	This sample contained very little suspended matter. We had fairly warm weather between August 23rd and 29th.	This sample has maintained its aeration fairly well. (The standard tubes were at this time somewhat weakened).

LEICESTER SEWAGE FARM, 1899–1900.

Brook Water, alone and admixed with Effluent.

132		133		133	134	135			135
General Effluent in equal proportions from each Outfall.		Brook Water above Effluent Outfall.		Duplicate.	Effluent and Brook Water mixed. Drawn 20 yards below Effluent Outfall.	Effluent and Brook Water. Drawn 180 yards below Effluent Outfall.			Duplicate.
Monday, 3rd Sept. 1900, 11.45 a.m.		Monday, 3rd Sept. 1900, 12.0 noon.		——	Monday, 3rd Sept. 1900, 12.30 noon.	Monday, 3rd Sept. 1900, 1.0 p.m.			——
15·0° C. (59° F.)		13·3° C. (56° F.)		——	13·9° C. (57° F.)	14·4° C. (58° F.)			——
17·2° C. (63° F.)		17·2° C. (63° F.)		——	16·7° C. (62° F.)	17·8° C. (64° F.)			——
——		——		Jointed 4th Sept. 1900.	——	——			Jointed 4th Sept. 1900.
4th Sept. 1900.		7th September 1900.		14th Sept. 1900.	5th Sept. 1900.	6th September 1900.			13th Sept. 1900.
						Same bottle.			
(A)	(B)	(B)	(A)			Unfiltrd. Effit. (B)	Filtrd. Effit.	Unfiltrd. Effit. (A)	
——		——		——	——	——	——	——	——
1·33	Lost.	0·08	0·03	0·02	0·27	0·33	0·32	0·24	——
0·31	Lost.	*0·03	0·07	0·05	0·06	*0·06	0·07	0·11	——
——	0·11	None.	——	None.	0·04	0·05	——	——	0·56
——	0·36	0·18	——	0·17	0·36	0·26	——	——	
——	2·29	0·31	——	——	0·85	0·48 (This must be wrong.)			——
——	(0·13 in 3·26)	(0·17 in 0·60)		——	(0·17 in 1·33)	——			——
——	+ ·06	None.	——	——	+ ·02	+ ·03	——	——	——
——	0·18	0·02	——	——	0·12	?	——	——	——
——	0·49	0·05	——	——	0·18	?	——	——	——
——		——		——	——	——			——
——		——		——	——	——			——
——	0·79	0·24	——	——	0·40	0·44	0·32	——	——
——	2·37	0·47	——	——	1·11	0·79	0·87	——	——
——	0·60	0·20 } 3 days	0·06 } 4 days	——	0·32	0·47	——	——	——
——	2.22	0·40	0·35	——	0·89	0·87	——	——	——
Slight earthy.		Not noted. Sure to be right.		——	Earthy.	Practically no smell.			——
——	12·24	2·30	——	——	5·56	4·60	——	——	——
		Total carbon dioxide.				Total carbon dioxide.			——
——		118·54	——	——	17·13 Not absolutely boiled out.	121·97	——	——	
——		6·29	——	——	5·74	†7·48	——	——	——
1·0 to 1·5 (Very green)	——	6·50	——	Nearly 6·0	5·50	5·8	——	——	1·5 to 1·75
——		14·04	——	——	14·20	14·03	——	——	——
Liquid clear but slightly yellow. Contained a little light-coloured matter in suspension. Earthy smell. Alkaline.		Liquid clear, with a small amount light brown flocculent matter. Very slight fishy-earthy smell. Distinctly alkaline. Very much lime. Much sulphate. No iron —or practically none.		This water has maintained its aeration well.	Liquid clear, but with appreciable amount of brownish flocculent matter. Fishy-earthy smell. Distinctly alkaline. Very much lime. Much sulphate. Little more than a trace of iron.	This looked very fairly clear, but it contained a small amount of brownish flocculent sediment. Slight fishy-earthy smell. Distinctly alkaline. Very much lime. Very considerable amount of sulphate.			

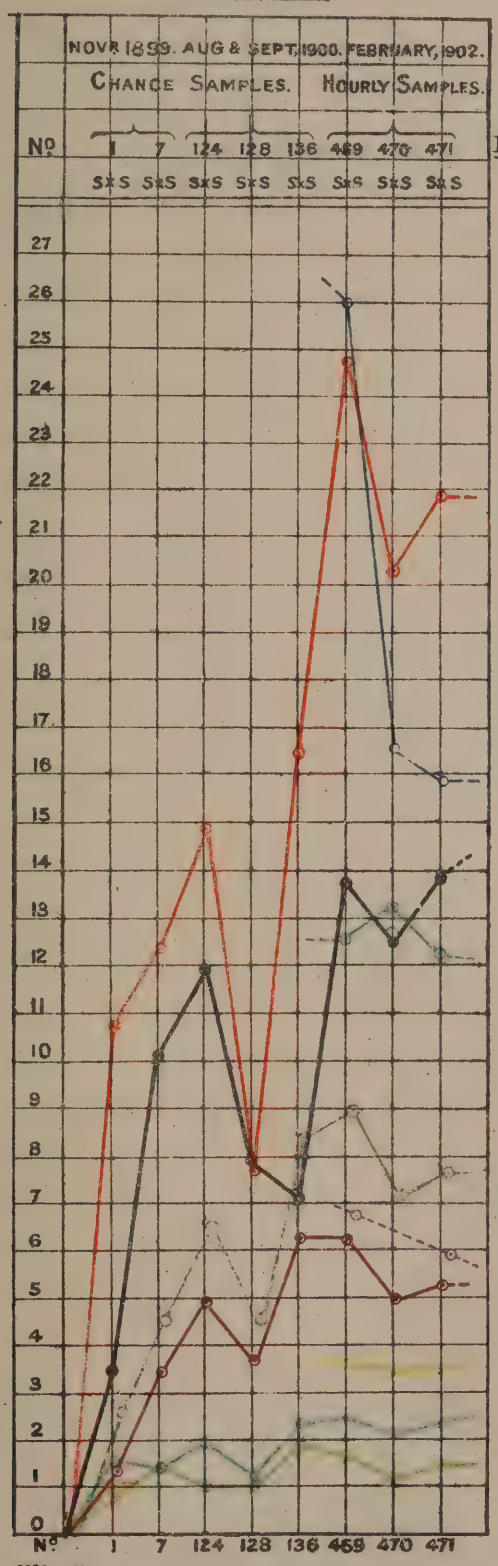
* It will be noted that the figures for albuminoid nitrogen do not agree well either here or in No. 135. The lower figures for albuminoid nitrogen are probably the better.

* See Note to No. 133.

† This will have been slightly affected by the nitrite.

Diagram No 23.

LEICESTER SEWAGE FARM.
SEWAGES.



Note, "S×S" means "Screened & Settled".

REFERENCE

Parts per 100.000, by Weight.

Albuminoid Nitrogen ..... *Shewn thus*

Organic Nitrogen by Kjeldahl, with Reduction ..... ,, ... ,,

Organic Nitrogen, by Kjeldahl, without Reduction ..... ,, ... ,,

Ammoniacal Nitrogen .....

Total Nitrogen by Kjeldahl, with Reduction ..... ,, ... ,,

"Oxygen absorbed" from Permanganate at 26·7°C (80°F.) in four hours .....

Chlorine (Combined) ..... ,, ... ,,

Solids in suspension, (Gravimetrically) (Scale divided by 10)

Cellulose ..... ,, ... ,,

Cellulose (still containing fat) ..... ,, ...

Parts per 100.000. by Volume.

Volume Solids in suspension, by Centrifuge (Scale divided by 10) .....

Note

"Figures in the Vertical line represent "Parts per 100.000."

Figures in the Horizontal Line represent the numbers of the Samples analysed.

A dotted line is used when there is a break in the curve.

3332. 7. 02.

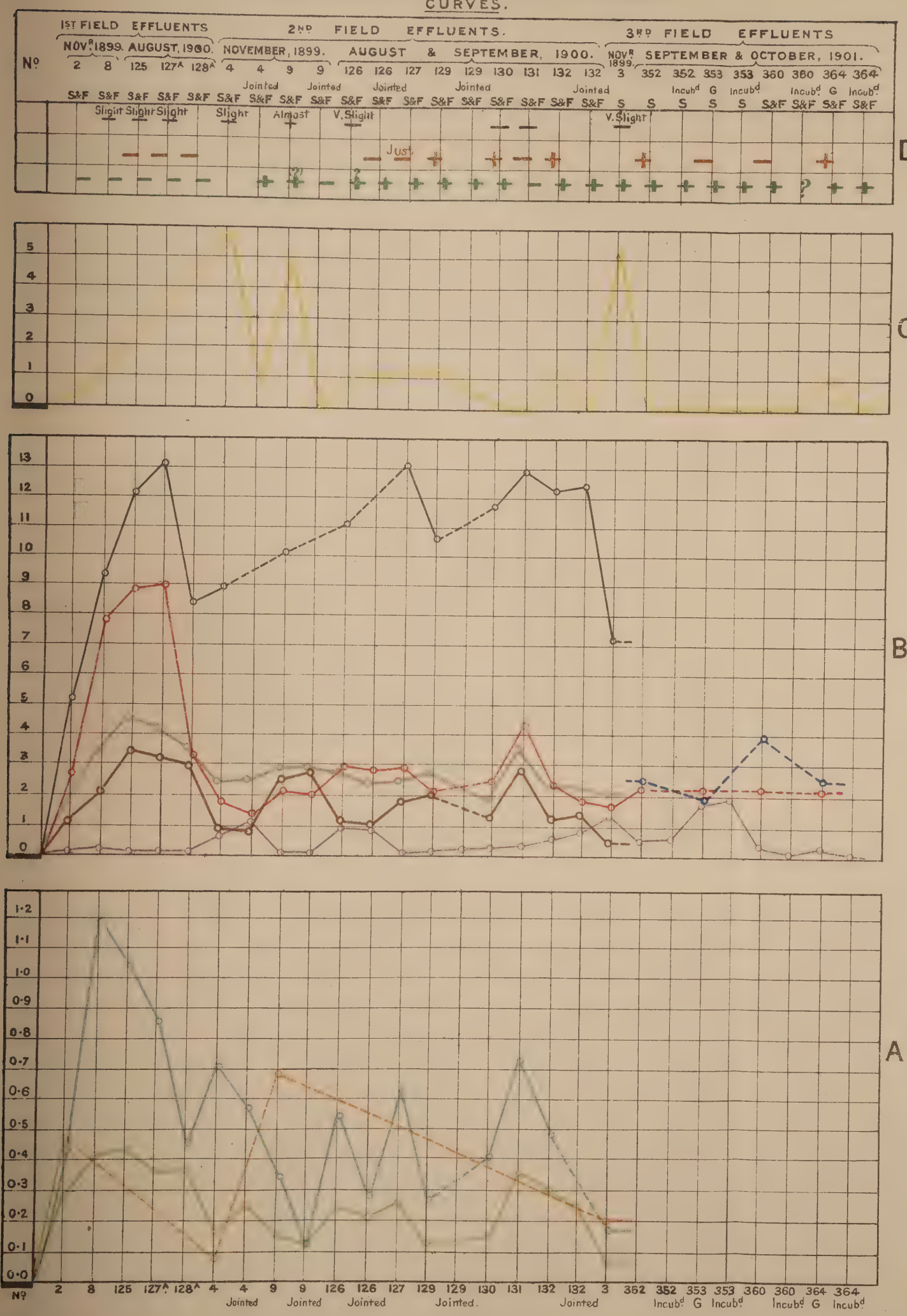
Weller & Graham Ltd Litho. London.

Diagram No. 24.

LEICESTER SEWAGE FARM.

1ST FIELD. 2ND FIELD & 3RD FIELD EFFLUENTS.

CURVES.



Note
S = Surface Effluent
F = Filtration " "
G = General " "

REFERENCE

Smell of Samples when drawn Shewn thus + or −

Scudder's Incubation Test + −

Incubation test as judged by Smell + −

Parts per 1,000, by Volume (C.C. per Litre)

Dissolved Oxygen when sample was analysed

Parts per 100.000, by Weight.

Ammoniacal Nitrogen. Shewn thus

Total Nitrogen by Kjeldahl, with Reduction.

Nitric + Nitrous Nitrogen (together)

"Oxygen absorbed" from Permanganate at 26·7°C (80°F.) in four hours.

Chlorine (Combined)

Parts per 100.000. by Volume.

Solids in Suspension (by Centrifuge) (Scale divided by 10)

Parts per 100.000, by Weight.

Albuminoid Nitrogen Shewn thus

Organic Nitrogen by Kjeldahl, with Reduction

Organic Nitrogen by Kjeldahl, without Reduction.

Note
Figures in the Vertical line represent "Parts per 100.000."

Figures in the Horizontal line represent the numbers of the Samples analysed.

A dotted line is used when there is a break in the curve.

Note
"Jointed" Indicates a sample jointed and allowed to stand at laboratory temperature.

"Incubated" Indicates a sample jointed and allowed to stand for five days or longer at a temperature of 26.7°C (80°F.).

3332. 8. 02.

Waller & Grahams Ltd Litho. London.

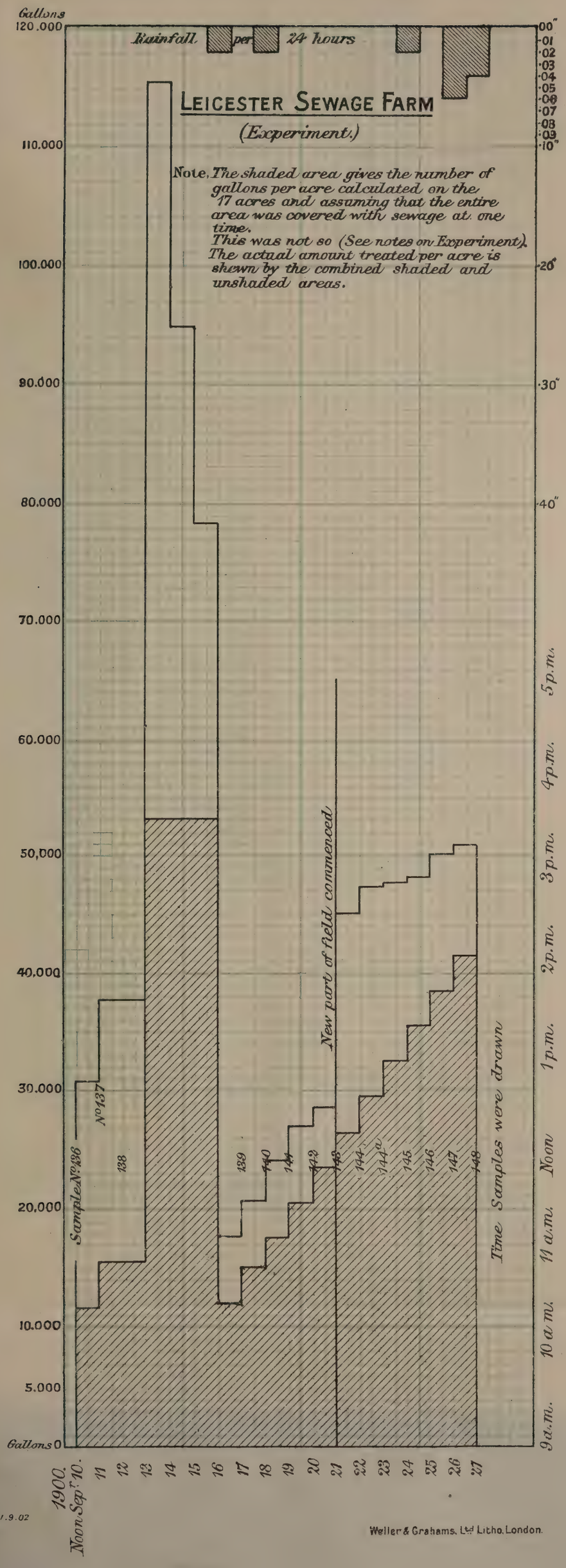


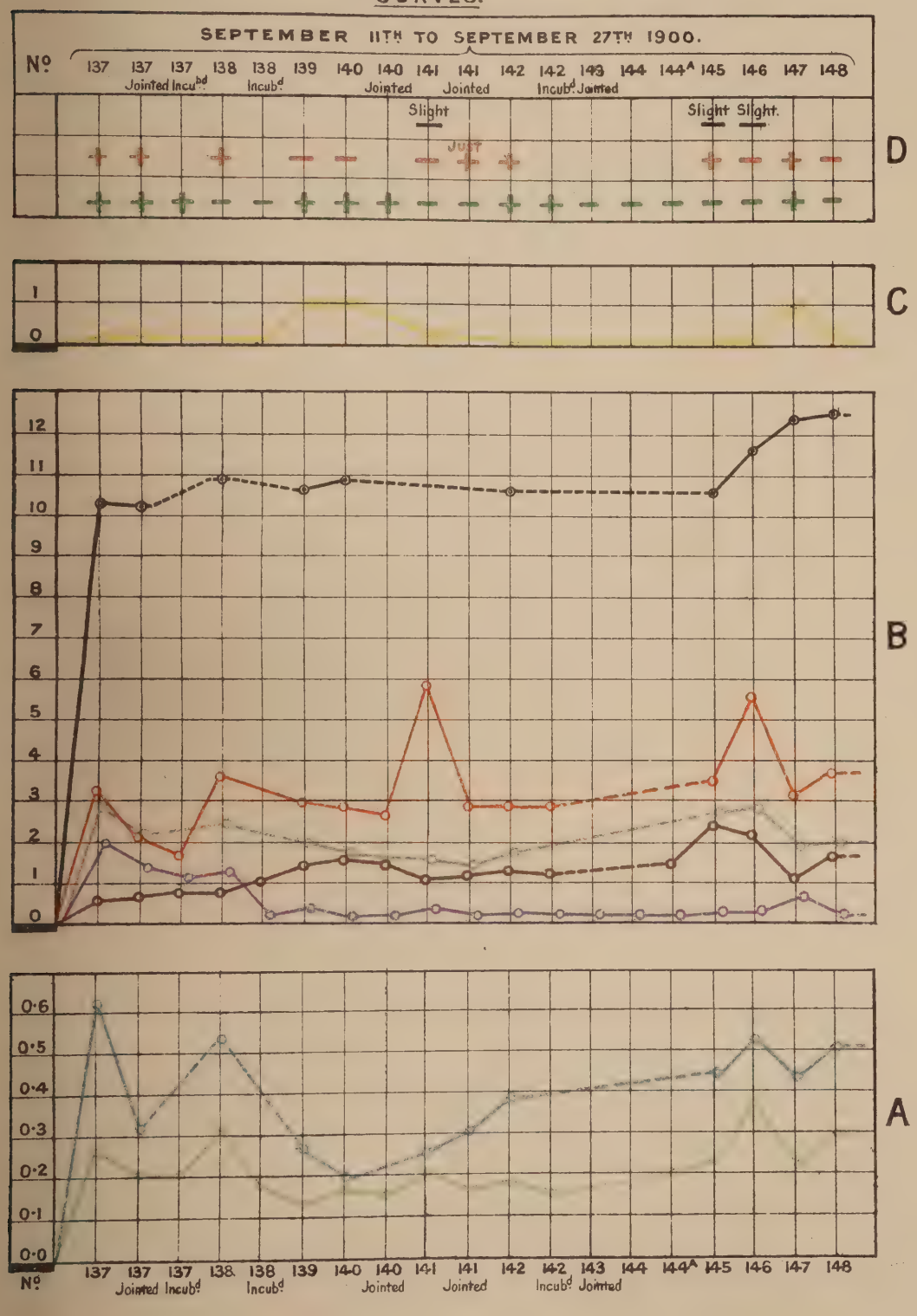
Diagram No. 25.
(Engineering Report Diagram)

3311.9.02

Weller & Grahams, Ltd Litho. London.

Diagram No 26.

LEICESTER SEWAGE FARM.
SPECIAL EXPERIMENT, 2ND FIELD EFFLUENTS.
CURVES.



REFERENCE

Smell of Samples when drawn Shewn thus + or —

Scudder's Incubation Test ..... + —

Incubation test as judged by Smell + —

Parts per 1.000, by Volume (C.C. per Litre)

Dissolved Oxygen when sample was analysed ——

Parts per 100.000, by Weight.

Ammoniacal Nitrogen ..... *Shewn thus* ——

Total Nitrogen by Kjeldahl, with Reduction ..... ——

Nitric + Nitrous Nitrogen (together) ..... ——

"Oxygen absorbed" from Permanganate at 26·7°C (80°F.) in four hours ..... ——

Chlorine (Combined) ..... ——

Parts per 100.000, by Weight.

Albuminoid Nitrogen ..... *Shewn thus* ——

Organic Nitrogen by Kjeldahl, with Reduction ..... ——

Note

Figures in the Vertical line represent "Parts per 100.000."

Figures in the Horizontal line represent the numbers of the Samples analysed.

A dotted line is used when there is a break in the curve.

Note

"Jointed" Indicates a sample jointed and allowed to stand at laboratory temperature.

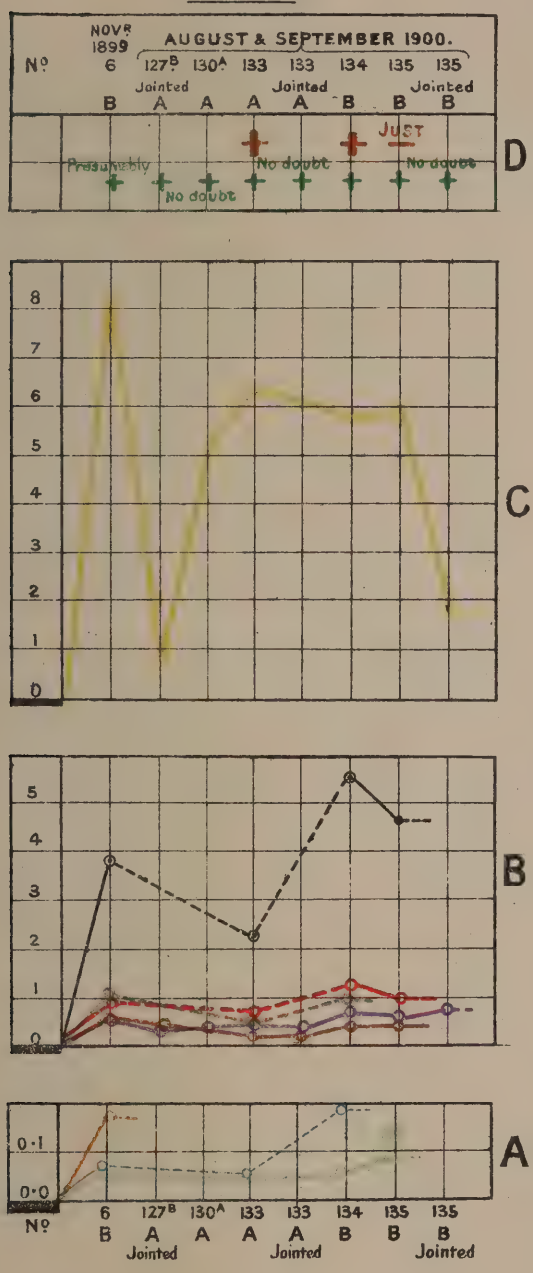
"Incubated" Indicates a sample jointed and allowed to stand for five days or longer at a temperature of 26.7°C (80°F.).

3392. 8. 02.

Weller & Graham Ltd Litho. London.

Diagram No. 27.

LEICESTER SEWAGE FARM.
BROOK WATER.
CURVES.



A Indicates a sample drawn from above Effluent Outfall
B " " " " " below " " "

REFERENCE

Scudder's Incubation Test + −

Incubation test as judged by Smell + −

Parts per 1,000, by Volume (C.C. per Litre)

Dissolved Oxygen when sample was analysed

Parts per 100,000. by Weight.

Ammoniacal Nitrogen. Shewn thus

Total Nitrogen by Kjeldahl, with Reduction.

Nitric + Nitrous Nitrogen (together)

"Oxygen absorbed" from Permanganate at 26·7°C (80°F.) in four hours.

Chlorine (Combined)

Albuminoid Nitrogen. Shewn thus

Organic Nitrogen by Kjeldahl, with Reduction.

Organic Nitrogen by Kjeldahl, without Reduction.

Note

Figures in the Vertical line represent "Parts per 100,000."

Figures in the Horizontal line represent the numbers of the Samples analysed.

A dotted line is used when there is a break in the curve.

Note

"Jointed" Indicates a sample jointed and allowed to stand at laboratory temperature.

3332. 8. 02

Weller & Graham Ltd Litho. London.

SOUTH NORWOOD SEWAGE FARM.

Chemical Report.

1. Situation of farm—Closely adjacent to South Norwood.
2. Total acreage of farm—191 acres.
3. Total irrigable area—152 acres.
4. Average area irrigated at one time—50 acres.
5. Population draining to farm—21,000.
6. Population per acre irrigated—138.
7. Gallons of sewage per head per day—28·5.
8. Dry weather flow of sewage per 24 hours—600,000 gallons.
9. Gallons of sewage treated per acre per 24 hours—12,000.
10. Gallons of sewage treated per acre per 24 hours, on the assumption that each acre of the irrigable area is under sewage all the time—4,000.
11. Character of the sewage—Purely domestic.
12. Method of treatment—Screening, settling tanks, and surface irrigation.
13. General character of the soil and subsoil—A clay soil resting on London Clay.
14. Separate or combined sewerage system—Partially separate.
15. The final effluent is discharged into—Chaffinch Beck.
16. Number of years farm in operation (before 1900)—36 years.

SOUTH NORWOOD SEWAGE FARM.

Like the sewage farms at Beddington and Rugby, that at South Norwood is of especial interest from having also been in its early days under the observation of the Rivers Pollution Commission (*Rivers Commission*, 1868, Vol. I., First Report, pp. 85-87). At that time (1868-69) 30 acres of clay land received the drainage of 4,000 people, *i.e.*, 133 persons per acre, which is about the same proportion as at the present day. Commenting upon the results of the bi-monthly analyses of effluent made during the year, the Commissioners say :—

> "These results, extending over an entire year, show that the effluent sewage was, except in a few instances, so far cleansed, even upon this heavy clay soil, as to be admissible into running water without nuisance."

t need hardly be said, however, that the results were in no way comparable with those obtained from the porous soil at Beddington during the same period.

As regards quality of soil and subsoil, the South Norwood farm is fairly comparable with that of Leicester, though the clay at the latter farm is apparently the stiffer. But there is this difference that, while the whole of the Leicester farm is underdrained at a depth of about 4 ft., only 25 acres are drained at South Norwood, and there he depth of the drains is 2 ft. The effluent from those drains is always treated again *over* a fresh piece of land ; hence, disregarding this small exception, the South Norwood effluents are to be regarded as *surface effluents obtained by broad irrigation over clay soil.*

The actual system of sewaging in vogue at South Norwood is described in the Engineering Report.* Suffice it to say here that the (screened and settled) sewage is treated over *two*, *three* or even *four* plots of ground, according to what is judged necessary. As at Beddington, the *whole* of the storm water (amounting on occasions to five times the dry weather flow) is treated.

The area irrigated at South Norwood now amounts to 152 acres, of which about *one-third* is under sewage at a time (at Leicester the proportion is one-fourth and at Beddington one-sixth). The whole of this irrigable area is under grass or crop at one time or another during the year.

* Part IV. : Engineering and Practical Report.

Soil and Subsoil.

The soil varies in depth from 6in. to 10in. It is on the whole a stiff heavy soil, which has in some parts been lightened by the addition of ashes, overlying a subsoil of the London Clay. Its mechanical analysis, etc., is given in the following table (the subsoil, being stiff clay, was not analysed) :—

SOUTH NORWOOD SEWAGE FARM.

Name of Fraction.	Surface soil per cent.			Subsoil per cent.		
	Not Ignited.	Ignited.	Difference.	Not Ignited.	Ignited.	Difference.
"Gravel" (above 8·0 m.m. diameter) - -	—	—	—			
Fine "Gravel" (above 2·0 m.m. diameter) -	2·40	1·62	0·78			
Coarse "Sand" (above 1·0 m.m. diameter) -	0·80	0·61	0·23			
Coarse "Sand" (above 0·5 m.m. diameter) -	0·85	0·63	0·22			
Medium "Sand" (above 0·25 m.m. diameter)	1·51	1·29	0·22			
" "Sand" (0·25 to 0·05 m.m.) - -	44·54	38·75	5·79			
"Silt" (0·05 to 0·01 m.m) - - - -	16·93	13·55	3·38			
"Dust" (0·01 m.m. and below, which settles from water in 24 hours) - - -	28·39	23·42	5·97			
"Clay" (the still finer residue precipitated from water by dilute nitric acid) - -	2·20	1·87	0·33			
Loss on ignition (separate determination) -		12·03				
	97·66	93·77	16·92			
Real specific gravity of soil dried at 110° C.	2·31					
Apparent specific gravity - - - - -	1·10 1·35					
Number of particles in 1 gramme of the ignited soil (approx.) - - - -	1,448,196,680					
Number of particles in 1 c.c. of the ignited soil (approx.) - - - - - - -	1,772,144,510					
Weight of water retained by 100 grammes of the (air-dried) soil when fully drained -	64·3 (?)					
Parts per 100,000.						
Lime dissolved by water in 24 hours - -	0·073			0·020		
Lime dissolved by water, saturated with carbonic acid, in 48 hours - - -	0·382			0·076		

For a discussion of the figures found in this table, *see* Section upon Soils, page 275.

Volume treated per acre, &c.

The South Norwood sewage is purely domestic.

The average dry weather flow is 600,000 gallons for a population of 21,000, or 28·5 gallons per head. The public water supply being 25 gallons per head, this allows 3·5 gallons for subsoil leakage into the sewers, which is but a small proportion.

Since the average area irrigated at one time is 51 acres each acre treats 11,800 gallons in 24 hours. But, on our usual assumption, *for purposes of comparison*, that the whole area is under sewage continuously, *each acre at South Norwood treats* 4,000 *gallons of screened and settled* sewage all the year round*. In times of storm, as already stated, this volume is largely increased. (*Cf.* Remarks on Street Surface Waters, page 321.

Three visits were paid to South Norwood, viz., in January, 1900, November and December, 1901, and January, 1902. It was not under observation during the summer.

Nature of Sewage. (*Diagram* No. 28.)

As already stated, this sewage is purely domestic, and it is screened and settled, a small portion being settled without screening. Judging from the figures obtained for suspended solids, the settlement must be fairly good on the whole (*cf.* Part IV.: Engineering and Practical Report).

Seven chance samples and seven sets of hourly samples were analysed, the hourly samples having been drawn *in equal quantities* every hour of the twenty-four. The latter, which are distinctly weaker than the chance samples, will be mainly referred to for any approximate calculations that may be made, though here again it must be remembered that they will represent a sewage somewhat weaker than what a true average, taken according to rate of flow, would have been. No rain fell while the hourly samples were being taken (in January 1902).

The chance samples were drawn in January, November and December, 1900, between the hours of 11 a.m. and 2.15 p.m., the sewage being apparently at its strongest from 12 to 1 o'clock. Among them is a sample of *crude* sewage (No. 170), but as it does not differ appreciably from the others it may be included. Unfortunately, neither the albuminoid nor the total organic nitrogen can be given for the first three of the chance samples (the weaker ones), owing to an error in the standard ammonia solution at the time.

It will be seen from a glance at the Curves that the chance samples were extremely uneven in composition, but the hourly ones tolerably even as regards nitrogenous matter, though not so in other respects. It is curious that throughout the whole of the samples, chance and hourly together, the chlorine should have been wonderfully constant, although the other curves are so uneven. The reason for these differences is no doubt to be found in the very unequal settlement of the sewage, as shown by the highly varying quantities of suspended solids in the different sets of hourly samples. Taken all over, this settled sewage is a weak one, at least in winter, both as regards dissolved and suspended matters.

The temperature of the three chance samples drawn in January, 1900, was in every case 7·7 deg. C. (46 deg. F.), while three of those drawn in November of that year had a temperature of 11·1 deg. C. (52 deg. F.), that of the remaining sample being 12·7 deg. C. (55 deg. F.); this last was the sample of *crude* sewage. Some of the chance samples are noted as dilute, and on the whole the amount of sediment in them does not appear to have been large (for a sewage); this points to efficient settlement *on the whole*, but the actual determinations of suspended solids made in the hourly samples show this settlement to have varied very much on different days, even though upon those days there was no rain and therefore no storm water.

The smell of the chance samples when analysed varied between "soapy," "very slight sewage," "sewage," "peppermint," and "sour." In the hourly ones an

* A small portion is settled only (*cf.* Part IV.: Engineering and Practical Report.)

absolute sewage smell was detected in the last two sets only, another being marked "clean," and another "earthy"—a further proof of their weakness. Small quantities of nitrate were found in four of the seven hourly samples—pointing to the presence of some, though probably not much, subsoil water. All the samples were alkaline in reaction.

The principal analytical results are summarised as follows :—

	Average.
Total Nitrogen—(*a*) 7 chance samples (3·52 to 10·84) - -	7·07
(*b*) 7 sets of hourly samples (4·46 to 5·63) - - - -	5·20
Ammoniacal Nitrogen—(*a*) 4 chance samples (5·35 to 7·60) -	6·50
(*b*) 7 sets of hourly samples (3·15 to 4·05) - - - -	3·54
Total Organic Nitrogen—(*a*) 4 chance samples (2·04 to 3·24) -	2·55*
(*b*) 7 sets of hourly samples (1·02 to 1·90) - - - -	1·49
Albuminoid Nitrogen—(*a*) 4 chance samples (0·98 to 1·23) - -	1·07
(*b*) 7 sets of hourly samples (0·55 to 1·04) - - - -	0·67
"*Oxygen absorbed*" *in* 4 *hours* at 26·7° C. (80° F.)—(*a*) 7 chance samples (6·74 to 20·08) - - - - - - -	11·40
(*b*) 7 sets of hourly samples (5·43 to 9·77) - - - -	7·71
Chlorine—(*a*) 7 chance samples (7·28 to 8·88) - - - -	7·87
(*b*) 7 sets of hourly samples (7·08 to 8·00) - - - -	7·45
Chlorine in water supply - - - - - - - -	1·3
Ratio of Ammoniacal Nitrogen to Chlorine—7 sets of hourly samples (1 : 1·86 to 1 : 2·37) - - - - - -	1 : 2·12
Ratio of Ammoniacal Nitrogen to Chlorine, after deducting the chlorine of the water supply—7 sets of hourly samples (1 : 1·52 to 1 : 1·96) - - - - - - - -	1 : 1·75
Solids in Suspension—7 sets of hourly samples (9·60 to 38·20) -	21·90
Solids in Suspension by Centrifuge (*Volumes*)—7 sets of hourly samples (80·0 to 245·0) - - - - - - - -	139·0
Ratios of Solids in Suspension to Centrifuge Solids (7 sets of hourly samples) - { 1 : 4·8, 1 : 5·9, 1 : 7·4, 1 : 4·7, 1 : 7·0, 1 : 7·6, 1 : 9·1 } -	1 : 6·6
Cellulose still containing fat, 7 sets of hourly samples (one extraction with dilute alkali and one with dilute acid) - - - - - - - - (2·80 to 12·84)	6·27
Ratios of Celluloses still containing fat to Suspended Solids, 7 sets of hourly samples - { 1 : 4·4, 1 : 3·8, 1 : 3·8, 1 : 3·0, 1 : 4·1, 1 : 4·3, 1 : 1·8 } -	1 : 3·6

The general points of similarity and dissimilarity in the various sewage curves have been already referred to, but a few further ones may be touched upon now.

The unevenness of the chance samples, excepting in the matter of chlorine, is very marked, but there is a fair resemblance—though not proportion in every case—between the five other curves for albuminoid nitrogen, total organic nitrogen, ammoniacal nitrogen, total nitrogen and "oxygen absorbed," *i.e.*, they rise and fall for the most

* As there may possibly have been a little nitrate (not estimated) in these samples, that would make the above figure for organic nitrogen rather too high.

part in unison, though in varying degree. In the hourly samples these curves again follow one another, and the variations are, of course, less marked in this case. The most interesting point about the curves of the hourly samples is, perhaps, the striking manner in which the albuminoid and organic nitrogen on the one hand, and the suspended solids on the other, rise and fall together. In the five last hourly samples the "oxygen absorbed" curve agrees well with these, but not in the two first.

To repeat, the sewage is, therefore, rather a weak one, containing in the hourly samples only 5·2 parts total nitrogen, 1·5 parts organic nitrogen (of which almost half is albuminoid), and 21 parts of suspended solids, and giving the low figure of 7·7 for "oxygen absorbed" from permanganate.

All the estimations of organic nitrogen were made by the Kjeldahl method *with reduction.*

The average ratio between albuminoid nitrogen and "oxygen absorbed" in the four chance samples of sewage is 1 : 13·0 and in the seven sets of hourly samples 1 : 11·3, but in both chance and hourly samples the ratio is an uneven one.

The average ratio between the figures for organic nitrogen and "oxygen absorbed" is in the chance samples 1 : 4·5, and in the hourly ones 1 : 5·2, which agrees fairly well with the same ratio for the sewage at Beddington (1 : 4·1 and 1 : 6·0), Cambridge (1 : 5·4), Aldershot Camp (1 : 4·8 and 1 : 4·1), and Rugby (1 : 5·6), all of which are domestic sewages or pretty nearly so. The Leicester figures, for a sewage containing much trade refuse, are totally different, *viz.*, 1 : 7·4 and 1 : 9·6.

The comparative evenness of the *chlorine* curve has been already referred to. In the hourly samples it gives a fair indication of the nitrogenous strength of the sewage but not in the chance ones.

Allusion has also already been made to the variations from day to day in the suspended solids of the hourly samples. The differences between the individual ratios in the figures for solids in suspension (gravimetrically) and volume solids respectively are too great for much deduction to be drawn here without further analyses being made, the extremes in the seven estimations being 1 : 4·7 and 1 : 9·1, average 1 : 6·6. Those variations are obviously the result of the unequal settlement of the sewage on different days, already referred to. At the same time this figure is exactly the same as the corresponding average ratio for Beddington (1 : 6·6), and very near to those for Rugby (1 : 6·4), Cambridge (1 : 6·0), and Leicester (1 : 5·8). The ratio figure for Aldershot Camp settled sewage (1 : 4·7) stands by itself.

Without, therefore, attempting to enter into this point here, or without laying much stress upon averages obtained from only a few analyses in each case, it would seem as if this ratio (about 6·5 : 1) was a fairly constant one for settled sewages of moderate strength (the Beddington sewage is screened only).

Only one estimation of true cellulose was made in the hourly samples of the South Norwood sewage, but the ratios between "cellulose still containing fat" and suspended solids were fairly even (excepting in No. 459), the average figure being 1 : 3·6. There is, however, no deduction to be drawn here.

First Field Effluents (*Diagram No.* 29.)

Four of these were examined :—Nos. 22, 25 and 27, in January, and No. 177 in November, 1900. The temperatures of the first three varied between 6·1 and 6·6 deg. C. (43and 44 deg. F.), while that of No. 177 was 9·4 deg. C. (49 deg. F.).

It will be seen from Mr. Kershaw's Notes * that, when those samples were drawn, the plots (three rye-grass and one fallow) had been sewaged continuously for either two or three days. He also states with regard to No. 27 that "the furrows of one of the arable fields ran longitudinally with the flow of the sewage, thus effecting very little purification." This last effluent (off arable land) ought to be comparable with No. 22 (off rye-grass), but it was by no means so good.

All the above effluents were turbid and contained considerable quantities of flocculent matter (there was not so much apparently in No. 177 as in the others). Only No. 177 had a sewage smell when it came to be analysed, the others being

* Part IV.: Engineering and General Report.

fishy or soapy. All were alkaline and all contained much lime and much sulphate in solution. It is noteworthy that No. 27 contained as much as between 2 and 3 c.c. of dissolved oxygen per litre when analysed.

Owing to an error in the strength of the standard ammonia solution used at the time, I cannot give the accurate figures for the ammoniacal, albuminoid and nitric nitrogen in the first three, but it will be seen that the total nitrogen in these four samples is reduced (roughly) by 33 per cent. as compared with the "corresponding" sewages, Nos. 21, 24 and 176, while the figures for "oxygen absorbed" show a diminution of 50 per cent. The first sample of effluent (No. 22) probably withstood incubation, but the others did not. The three which were boiled out showed the moderate amounts of free carbonic acid that one finds in surface effluents.

The passage over one field of rye-grass or fallow has thus effected a substantial, though of course, quite inadequate, purification of the sewage.

Second Field Effluents. Diagram (No. 29.)

Three ordinary samples of these were analysed, viz., Nos. 26, 29 and 171, the first two in January and the third in November, 1900. Their temperatures were respectively 5 deg., 6·6 deg., and 10 deg. C. (41 deg., 44 deg., and 50 deg. F.) All the plots—rye-grass in every case—had been sewaged continuously for two days before the samples were drawn.

In appearance and composition those second field effluents, showed a marked improvement upon the first field ones. They were partly opalescent, and partly brown or lemon coloured, with only small amounts of suspended flocculent matter (*see* Notes to Analyses), and they had a clean earthy smell. The two tested for reaction were alkaline and contained much lime and a considerable quantity of sulphate in solution.

For the reasons already stated under the first field effluents, the exact figures for the ammoniacal, albuminoid and nitric nitrogen cannot be given for Nos. 26 and 29, but a glance at the other figures of analysis and at the curves shows that these effluents were of very fair quality indeed. Nos. 26 and 171 still contained 5 and 3 c.c. of dissolved oxygen when analysed, and No. 29, 1 c.c. The figure for "oxygen absorbed" was in no case high, and all the samples withstood the incubation test as judged by smell; No. 26 failed to pass Mr. Scudder's incubator test, and No. 29 barely passed it.

In Nos. 26 and 29 there was a fair amount of nitrate. No. 171 was a very dilute sample as regards nitrogenous matter of any kind, on account of a heavy rainfall, though it was really less purified, *relatively*, than the other two.

Sample No. 26 is comparable with the first field effluent No. 25, and it will be seen that the "oxygen absorbed" figure shows a reduction of fully 50 per cent.

These second field broad irrigation effluents, therefore, while not of a high class, are fair.

NOTE.—In No. 171, the two determinations of organic nitrogen by Kjeldahl, with and without reduction, did not agree well, the method *without* reduction giving probably too low a result.

Third Field, Fourth Field, and Combined or General Effluents. (Diagram No. 29.)

Nine of these were analysed, one of them in duplicate after incubation. Of these, Nos. 31, 35 and 184 were general effluents, No. 175 was treated over four fields, and the remaining five over three fields. It must be noted here that the three general effluents contained the effluent from the South Norwood bacteria beds, after it had been subsequently passed over land, but the volume of this relatively to the whole volume of effluent was small at that time. None of the other final effluents contained this.

The temperatures of Nos. 23, 30, 31 and 35, drawn in January, 1900, varied between 3·3 deg. and 7·2 deg. C. (38 deg. and 45 deg. F.), while the other five,

drawn in November of the same year, were slightly warmer, *i.e.*, they ranged between 6·6 deg. and 8·8 deg. C. (44 deg. and 48 deg. F.).

These effluents varied in appearance, the general effluents evidently containing rather more suspended matter than the others; but it is only fair to note that when No. 31 (a general effluent) was drawn, the rainfall had largely increased the flow, and there had also been heavy rains previous to the drawing of No. 35, another general effluent. From an excellent looking effluent with a slight brown tinge and only a trace of flocculent matter (No. 180), there were others which were turbid, and with appreciable amounts of matter in suspension. The smell, when the samples came to be analysed, varied from fishy to earthy. The few samples which were tested for reaction were alkaline, and they contained a great deal of lime and a good deal of sulphate in solution.

The remarks made in the Croydon (Beddington) Report with regard to the difficulties caused by the sudden increases in flow due to storm water apply to South Norwood also, and as the soil there is much less porous than at Beddington, they must apply with even greater force.

The following figures show some of the more important average results from the examination of 6 to 11 effluents, 6 for ammoniacal and albuminoid nitrogen and 11 for total nitrogen and "oxygen absorbed," These include three 2-field effluents. Details are given in the annexed Tables of Analysis and Curves.

	Average.
Total nitrogen (0·55 to 2·83) - - - - - - -	2·30
Ammoniacal nitrogen (0·02 to 1·55) - - - - - -	0·87
Albuminoid nitrogen (0·07 to 0·14) - - - - - -	0·10
Nitric + nitrous nitrogen together (0·14 to 0·74 (?)) - - -	0·39
"Oxygen absorbed" from permanganate at 26·7° C. (80° F.) in 4 hours (0·97 to 1·73) - - - - - - - -	1·44
Incubator test (as judged by smell) - - - -	75 per cent. passed. (12 samples tested.)

The analytical tables and curves are again unfortunately incomplete as regards the first four samples (Nos. 23, 30, 31 and 35), which makes any detailed criticism more difficult, but the samples drawn in November, 1900, appear to have been rather better on the whole than those drawn in January, though they certainly contained much less dissolved oxygen when analysed. Two of the January samples (Nos. 31 and 35) had as much as 5 to 6 c.c. per litre of *dissolved oxygen* when analysed, and No. 30 about 3 c.c., the amounts in the four others tested being about 1 c.c. in each case; but when the January set of samples were drawn and analysed the temperature was lower. The gases in the January samples were boiled out. It will be noticed that the five (Nos. 171, 175, 178, 180, and 184) tested for dissolved oxygen, *when drawn*, did not apparently give high results, the maximum figure being 3 c.c.; but as these effluents were all more or less coloured, the comparison with the standard copper chloride tubes was difficult; hence those dissolved oxygen figures in the November samples must be taken as being almost certainly below the true value, and no real conclusions can be drawn here.

The free *carbonic acid* in the four samples boiled out varied between 24·1 and 31·5 c.c. per litre, *i.e.*, it was moderate in amount, as one would naturally expect from a somewhat dilute surface irrigation effluent.

In four cases out of six the smell of the effluent when drawn—good or bad—agreed with the smell after incubation.

The *ammoniacal nitrogen* in five effluents drawn in November varied between 0·70 and 1·55, average 1·02. It thus constituted about half of the total nitrogen.

The *albuminoid nitrogen* in the five effluents drawn in November (one of them incubated), varied between 0·07 and 0·14, average 0·10. All of them kept on incubation (as judged by smell), excepting probably No. 180, which had for its albuminoid

nitrogen the low figure of 0·08. The rye-grass plot from which this last was drawn had been sewaged for three days, but there was no rain on the day of drawing, and only a little the day before.

The figures for "*oxygen absorbed*" ranged in eight effluents between 1·01 and 1·73, average 1·46.

The average ratio of albuminoid nitrogen to "oxygen absorbed" from permanganate in 4 hours, after allowing for nitrite present, is in five effluents 1 : 14, the extremes being 1 : 10 and 1 : 19. This is a higher ratio than that at some of the other farms, but the analyses are too few here to allow of deductions.

Incubation. Mr. Scudder's test was rather more stringent here than the test as judged by smell, condemning four out of eight effluents. Out of seven comparable cases, this test agreed in four or five with the incubation result as judged by smell and disagreed in two or three.*

The *total nitrogen* in the effluents varied between 1·74 and 2·83, the average for eight effluents being 2·30 (the corresponding Beddington figure for sixteen effluents was 2·20). It will be seen from the curve that the total nitrogen was distinctly less in November than in January, indicating probably a greater absorption by the vegetation during the former month. The excessive rainfall on the day on which No. 35 was drawn had evidently not had time to make itself felt.

The *total organic nitrogen* in the four effluents Nos. 175, 178, 180 and 184 varied between 0·33 and 0·41, which is nearly four times as much as the albuminoid nitrogen in the same effluents—a very high ratio. Unfortunately, the corresponding figures are not available for the other effluents, for the reasons already given. (The figures obtained by the method of Kjeldahl *with* reduction have again been taken here, as being on the whole preferable to those obtained by the method *without* reduction—*see* Curves; though possibly the latter was the better in the case of No. 178. In No. 180 the two methods agreed absolutely.)

Excepting in No. 23, which contained 0·13 part of *nitrous nitrogen*, the figure for the latter in other seven effluents was very small—between 0 and 0·04.

The *nitric* (including nitrous) nitrogen in the five effluents Nos. 175, 178, 180, 180A (incubated) and 184 varied between 0·14 and 0·74 (or possibly 1·08 ?)—average 0·41—a low figure. Only one *duplicate* sample, No. 178, was incubated; this was a good sample, and lost no nitrate in the process. No. 180A also withstood incubation, and still retained a little nitrate. But the data are altogether insufficient for any conclusions to be drawn here as to the extent to which the nitrate of the South Norwood effluents is drawn upon during incubation by the dissolved organic matter present.

The *Ratio of Oxidised to Unoxidised Nitrogen* in the five samples Nos. 171 †, 175, 178, 180, and 184 (taking the unoxidised = 1) varies between 0·07 and 1·2, but there are too few analyses to allow of any deductions being drawn, especially as the results are in part contradictory. Probably a somewhat high ratio would be required for safety as the sewage is a dilute domestic sewage. The same remark applies to the *Ratio between the Oxidised and the Albuminoid Nitrogen.*

The *Chlorine* curve of the effluents, like that of the sewages, is a singularly even one.

In conclusion.—The South Norwood Farm treats a relatively small volume of a rather weak sewage and a relatively small amount of organic matter per acre of irrigable area (*cf.* Diagrams Nos. 3 and 4). The clayey surface soil is not a very deep one,—only 6 inches to 10 inches, but it has been to some extent improved and lightened by the digging in of ashes, and also, of course, by the sewaging which it has received. Taking the number of particles in unit weight of the Nottingham ignited surface

* In these effluents the amount of nitrous nitrogen was not noted after incubation, and it is assumed that it was not greater than before it.

† This dilute 2-field effluent is included here.

soil as 100, the soil at South Norwood contains 177; the corresponding number in unit volume is 150. So far as one can draw a conclusion from the analyses of the final and general effluents—which are fewer in number than might have been wished—these effluents were of moderate quality, the land having evidently had rather too much to do in January and November 1900. This was fully recognised by the authorities, who were at that time extending their bacterial filters. As has been already noted, the difficulty of treating sewage by broad irrigation on a clay soil, in which the aggregate effective surface for purification is small, must be greatly added to by sudden and irregular flushes of storm water. It seems also open to question whether it is advisable to continue sewaging one plot of ground for so long a period (from two to four days) as is actually done at South Norwood. It would make an interesting and useful experiment to try (not merely at South Norwood but at other farms also) the separate effects of treating equal quantities of the same sewage on equal areas of ground, but in the first case with more frequently intermittent doses than in the second.

Final and General Effluents.

Percentage purification as calculated on the Albuminoid Nitrogen and "Oxygen absorbed" in four hours.

		Average.
(1) *Albuminoid nitrogen.*		
(*a*) 4 chance samples of screened and settled sewage yielded - - - - - - -	0·98 to 1·23 -	1·08
(*b*) 7 sets of hourly samples - - -	0·55 to 1·04 -	0·67
5 final effluents (3-and 4-field and general) yielded	0·07 to 0·14 -	0·10

Percentage Purification.

(*a*) Calculated on the chance samples of sewage - -	90·7 per cent.
(*b*) ,, ,, hourly ,, ,, - -	85·1 ,,

(2) *Oxygen absorbed.*		
(*a*) 7 chance samples of sewage yielded -	6·74 to 20·08 -	11·40
(*b*) 7 sets of hourly samples - - -	5·43 to 9·77 -	7·71
8 final effluents (3-and 4-field and general)	1·01 to 1·73 -	1·46

Percentage Purification.

(*a*) Calculated on the chance samples of sewage - -	87·1 per cent.
(*b*) ,, ,, hourly ,, - -	81·1 ,,

Comparison of the total nitrogen in the sewages and in the final and general effluents.

	Average.
The total nitrogen (*a*) in 7 chance samples of sewage was 3·52 to 10·84	7·07
(*b*) in 7 sets of hourly samples 4·46 to 5·63 - -	5·20
The total nitrogen in eight 3-and 4-field and general effluents was 1·74 to 2·83 - - - - - - - - - - - -	2·30

The real nitrogenous strength of the screened and settled sewage will probably lie between the figures 7·07 and 5·20, or, at all events, above the smaller of these. Again, as stated by Mr. Kershaw, there is no subsoil water on the farm, but the volume of effluent must at times have been increased by rainfall and storm water. If

we neglect this gain by rainfall on the one hand and the loss by evaporation from the rye-grass on the other, the conclusion is that in autumn and winter something like one-third of the total nitrogen of the screened and settled sewage finds its way into the brook.

Experiment to see how much sewage a given area of the land would stand. (*Diagrams Nos.* 30, 31 *and* 32).

At South Norwood a similar experiment was made to those at Beddington and Leicester, with the object of seeing how long the soil would retain its power of purifying sewage under a daily increasing dose. It began on November 27th, 1900, and ended on January 2nd, 1901, although only two samples were drawn after December 20th, 1900.

As circumstances would not allow of the usual South Norwood system of sewaging being carried out, the following procedure was adopted. To summarise from Mr. Kershaw's Notes :—

Two uncropped arable plots were set aside for this experiment, their areas being 1·25 and 1·0 acres respectively. These had not been sewaged since February, 1900, *i.e.*, for ten months, but they had borne a crop of mangolds in the summer, no artificial manure having been applied to the land. Two days before commencing the experiment the plots were freshly ploughed eight inches deep, leaving the ridges fairly high, a point which had an important bearing upon the results. The sewage was treated *twice*, being run from the first on to the second plot. *All the effluents were therefore surface effluents off uncropped heavy soil.*

A reference to Diagram No. 30, prepared by Mr. Kershaw, which is reproduced here, and to the accompanying table given in the Engineering Report,* shows at a glance the *actual* number of gallons of sewage treated per acre per day on each plot. It will be seen that the second field invariably received much more, proportionately, than the first, these differences being due partly to the varying areas of ground which took the sewage and partly to rain collecting in the first field and mixing with the sewage there.

It will be remembered that the average quantity of dry weather sewage treated by an acre at South Norwood, under actual irrigation in the ordinary way, is about 12,000 gallons per 24 hours ; $2\frac{1}{4}$ acres would therefore, at this rate, treat 27,000 gallons. The actual dose applied at first, on November 26th–27th, was 15,000 gallons, reckoned on the surface actually sewaged, the normal value being reached (theoretically) between December 2nd and 3rd. On December 20th the flow on to the first field was 39,000 gallons, or nearly twice the normal amount.

Mr. Kershaw's "Additional Notes on Samples," and that part of the Engineering Report which deals with the subject, should be read along with this.*

First Field Effluents. (*Diagram No.* 31).

Eighteen of these first field effluents were examined, for the most part only partially, but two of them in duplicate after incubation (Nos. 181 and 183). The greater number of these samples were small ones, hence twelve out of the eighteen—besides the above two duplicates—were incubated before being analysed.

As regards temperature when drawn, they varied very little indeed. If we omit the last sample, No. 199, whose temperature was 6·1 deg. C. (43 deg. F.), the extremes of all the others were only 7·2 deg. and 9·4 deg. C. (45 deg. and 49 deg. F.). In the greater number of the samples there was comparatively little sediment, the land having acted well in this respect. As to smell when drawn, the first three samples were not noted, but No. 186A, drawn after the land had been sewaged for four days, had no smell, and No. 187B, drawn after five days, had presumably no smell ; 187D, however, drawn after seven days sewaging, had a slight smell. From that date down to the end of the experiment all the first field effluents smelt of sewage when drawn, *i.e.*, they were not really purified efficiently.

* Part IV. : Engineering and Practical Report.

But it will be seen from a glance at the Curves, that, excepting No. 190, they all kept upon incubation up to No. 194A, this being due to the abnormally large amount of nitrate which they extracted from the soil, nitrate no doubt stored up during and since the growth of the mangolds. And this period of extraction was unduly prolonged for two reasons, *viz.*, (1) because it was only when half way through the experiment that this whole plot was (nearly) covered with liquid, and (2) because the land being still in ridges, the soil of those ridges gave up its nitrate very gradually, according as the sewage soaked up into it. The sudden rise in nitrate in No. 191A (incubated), after the reserve in the soil had been apparently exhausted, can only be accounted for in this way.

The other curves call for little comment, excepting that those for ammoniacal and albuminoid nitrogen and "oxygen absorbed," up to No. 187B (five days' sewaging), show that the purification effected on the sewage by this one-field treatment was very considerable indeed.

The remainder of the first field effluents were only of interest from the point of view—how long would the nitrate present stand them in good stead during incubation, a subject which has already been entered into.

Second Field Effluents. (*Diagram No.* 32).

Sixteen second field effluents were examined, four of them in duplicate after jointing or incubation. (Reference should again be made to Mr. Kershaw's diagram, his Table of volumes of sewage going on to the land, and his additional Notes on samples.*)

In temperature the second field effluents varied a *little* more than those from the first field. Leaving again out of account the last sample, No. 200, which had the lowest temperature, 5 deg. C. (41 deg. F.), that of the others ranged from 6·1 deg. to 10 deg. C. (43 deg. to 50 deg. F). Excepting No. 187 (2), they were either clear or nearly clear until the last few samples were reached, these being slightly dim or turbid, and the colour was usually lemon. The removal of the suspended solids of the sewage by those two plots of arable land was therefore distinctly good.

Up to No. 187C (four days' sewaging), they had a clean smell when drawn, but after that, or at all events from No. 188 (eight days' sewaging) onwards, they smelt more or less when drawn, with the exception of No. 195. Any smell, however, had altogether disappeared by the time the samples came to be analysed, all of them being noted then as clean, earthy, or slightly fishy-earthy, with the exception of No. 194D (slight sewage smell) and No. 200 (fishy or soapy). It is probable that No. 194D had been affected by a rather heavy rainfall on the preceding day.

A study of the curves reveals much the same state of matters as in the case of the first field effluents, though the second field ones are, of course, of better quality; hence it is hardly necessary to dwell much upon them. It will however be noted that neither the albuminoid nitrogen nor the "oxygen absorbed" ever went down very low. Up to No. 194D there was generally a small quantity of dissolved oxygen in these effluents when they came to be analysed (a good sign), and a similar large reserve of nitrate to what was found in the first field ones, so that up to this point (after eighteen days' sewaging) the nitrate sufficed to keep the effluent good on incubation. Even No. 198 (after twenty-three days' sewaging) had recovered a sufficient reserve to effect the same end. With effluents containing such abnormal quantities of nitrate (and sometimes of nitrite) I do not wish to lay much stress on the figures obtained for organic nitrogen (by the Kjeldahl method *with* reduction). It is probable that in some cases the nitrate was under-estimated and the organic nitrogen therefore over-estimated (compare Remarks upon this point in the Section relating to the Aldershot Camp Farm, and also in the Report dealing with Methods of Chemical Analysis†). The Kjeldahl method *without* reduction gave too low results. But the value of estimating the total nitrogen, as a check on the individual estimations of nitrogen in its various forms, is perhaps more than usually noticeable in these two sets of effluents.

---

* Part IV.: Engineering and Practical Report.

† Part V.: Report on Methods of Chemical Analysis as applied to Sewage and Sewage Effluents.

It will be noticed that the chlorine in the earliest second field samples was excessively high, the nitrate being comparatively low. This was no doubt due to the greater solubility of chloride, or to its lesser retention by the soil, in presence of a small flow of liquid.

As the conditions of this experiment were decidedly abnormal, both because of the large reserve of nitrate in the soil and the slow way in which this nitrate was given up, and also because of uncropped arable land only having been used, one cannot safely draw any further conclusions from the results with regard to the purification which the South Norwood farm might ordinarily effect.

Surface Water from Streets.

Four samples of street washings were obtained by Mr. Kershaw during his stay at South Norwood, *viz.*, Nos. 174, 179, 182 and 187A, all drawn between November 14th and December 21st, 1900.

No. 174.—Surface water from streets and front roofs, which was drawn during sharp showers, the weather having also been showery on the day previous, was not particularly impure, and it kept sweet upon incubation; there was a great deal of sand in it.

No. 179.—Surface water from streets after moderate showers, the streets having been washed fairly clean by previous rain, did not contain much sediment, but was organically much more impure than the preceding sample and became putrid upon incubation. Mr. Kershaw wrote at the time:—"Nos. 174 and 179 will be fair samples of street washings, as no other water but (periodically) that from the South Norwood baths enters the culvert." This water ultimately joined the sewage from the settling tanks.

No. 182.—Another street surface water, was drawn after the surface drain had been running for 3 hours. It was very turbid and brown, and contained much grit. Organically it might be classed as a dilute sewage.

No. 187A.—Surface water from streets after a slight rainfall, though it showed a good deal of dark-coloured flocculent sediment after incubation, kept sweet.

These few examples are sufficient to indicate the additional burden thrown on the farm by the irregular flow of storm waters. (For details, see Tables of Analysis.)

Water from the Chaffinch Beck, alone and admixed with Effluent. (*Diagram No.* 33.)

In the Engineering Report,* Mr. Kershaw says that the Chaffinch Beck, into which the farm effluent flows, has only a very small volume, the latter frequently not exceeding that of the effluent even in winter; in dry seasons very little effluent leaves the farm at all, owing to evaporation. He states, too, that the Beck water evidently receives a certain amount of pollution from surface water drains, which join the effluent ditch *before* the effluent itself flows into the brook.

Only four samples were examined, *viz.*, Nos. 32, 33, 34 and 180B; the first three of these are comparable with the effluent No. 31, all four having been drawn on January 30th, 1900.

No. 31 (the effluent itself) has been already spoken of. It was a general effluent, whose flow had been largely increased by rain; though still well aerated on the day of analysis, it was otherwise only of very moderate quality.

No. 32 represents the Beck water alone, the sample having been drawn 20 yards above the effluent outfall. Mr. Kershaw states in his Notes* that the stream did not appear to be in very good condition at the time, and that its volume had been considerably augmented by recent rain. Unfortunately only part of the figures of analysis are available with regard to this and the other comparative samples, but these showed the Beck itself above the effluent outfall to be in a fairly satisfactory

NOTE.—Though the table of curves gives Nos. 32, 33 and 180B as having been condemned by Mr. Scudder's incubation test, the first two were only *just* over the mark.

* Part IV.: Engineering and Practical Report.

state at the time, for a non-drinking water stream. No. 32 was fully aerated when analysed, but on the other hand it contained an appreciable amount of brownish flocculent matter.

No. 33, drawn 20 yards below the effluent outfall, shows the admixture of effluent with Beck water very plainly. The curves, both of the total nitrogen and of the chlorine, make the volumes of the two to be pretty nearly equal.

No. 34, drawn a quarter of a mile lower down the Beck, gave an analysis very similar to that of No. 33. All of these samples, 32, 33 and 34, were very well aerated when analysed, and all kept sweet upon incubation.

No. 180B, drawn in November, 1900, 55 yards below the effluent outfall, ought to be fairly comparable with No. 33. It was not, however, quite so satisfactory, though it kept good on incubation.

While therefore there was no question of nuisance arising from this stream at the time, the presence of sewage weed, observed by Mr. Kershaw, and the somewhat high figures obtained for "oxygen absorbed" show that, from one cause or another, the little brook was not in too satisfactory a state at the time the above few observations were made.

SOUTH NORWOOD SEWAGE FARM.

TABLES OF ANALYSIS.

INDEX.

	PAGE.
Hourly Sewage Samples, Nos. 453–459	170–171
Sewage and Effluents, Nos. 21, 22, 23	172
„ „ Nos. 24, 25, 26, 27	173
„ „ Nos. 28, 29, 30, 31, 35	174–175
Sewage, Artificial Storm Water and Effluents, Nos. 170, 171, 175	176
Sewage and Effluents, Nos. 176, 177, 178, 180, 180A, 184	177

Special Experiment :—

Sewage, Artificial Storm Waters and Effluents, Nos. 181A–181A (5), 181, 183	178–179
Effluents, Nos. 185A, 185, 186A, 186, 187B, 187C, 187D, 187	180–181
„ Nos. 188A, 188, 189A, 189, 189B, 189C, 190, 191	182–183
„ Nos. 191A, 192, 193	184
Sewage and Artificial Storm Waters, Nos. 193A, 193A (1)–193A (4)	185
Effluents, Nos. 194, 194A, 194B, 194C, 194D, 195A, 195	186–187
„ Nos. 196, 197, 197A, 198, 199, 200	188–199
Surface Waters from Streets, Nos. 174, 179, 182, 187A	190
Brook Water above and below Effluent Outfall (including one Effluent), Nos. 31, 32, 33, 34, 180B	192–193

SOUTH NORWOOD SEWAGE FARM, 1902.

Hourly Sewage Samples drawn in Equal Quantities per Hour.

No. of Sample	453	454	455
Nature of Sample	Screened and Settled Sewage. 24 Hours' Sample.	Screened and Settled Sewage. 24 Hours' Sample.	Screened and Settled Sewage. 24 Hours' Sample.
Rainfall while sample was being drawn	Inches. 0·0	Inches. 0·0	Inches. 0·0
Drawn	From Monday, 13th January 1902, 5 p.m., to 14th January, 4 p.m.	From Tuesday, 14th January 1902, 5 p.m., to 15th January, 4 p.m.	From Wednesday, 15th January 1902, 5 p.m., to 16th January, 4 p.m.
Analysed	15th January 1902.	16th January 1902.	17th January 1902.
Parts per 100,000, *by weight.*			
Ammoniacal nitrogen	3·64	4·05	3·15
Albuminoid nitrogen	0·55	0·62	0·75
Nitrous nitrogen	0·06	0·06	0·02
Nitric nitrogen	0·28	0·27	None
Total nitrogen by Kjeldahl, *with* reduction	5·52	5·63	4·78
Blank	(0·26 in 4·29)	(0·26 in 4·37)	(0·26 in 3·75)
"X" nitrogen	0·99	0·63	0·86
Organic nitrogen by Kjeldahl, *with* reduction	1·54	1·25	1·61
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once*	1·52	1·83	1·31
" " " *after four hours*	8·26	9·77	7·87
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80·° F.); *at once*	1·41	1·76	2·54
" " " *after four hours*	6·17	6·14	7·34
Smell after incubation	Putrid, but not blackened	Putrid; smell of sulphuretted hydrogen.	Putrid; sulphide smell.
Chlorine	7·34	7·54	7·08
Total solids (gravimetrically)	96·0 { 36·4 volatile, 59·6 non-volatile }	100·2 { 41·4 volatile, 58·8 non-volatile }	99·8 { 37·2 volatile, 62·6 non-volatile }
Solids in suspension	19·0 { 14·6 volatile, 4·4 non-volatile }	20·4 { 19·0 volatile, 1·4 non-volatile }	22·6 { 15·4 volatile, 7·2 non-volatile }
Solids in solution	77·0 { 21·8 volatile, 55·2 non-volatile }	79·8 { 22·4 volatile, 57·4 non-volatile }	77·2 { 21·8 volatile, 55·4 non-volatile }
Cellulose still containing fat (by extraction with alkali and acid alone) (a)	4·28	5·36	5·88
" (by alkali, acid and ether) (b)	——	——	2·88
Grit — From (a)	1·48	1·48	2·52
Grit — From (b)	——	——	2·60
Parts per 100,000, *by volume.*			
Solids by Centrifuge	92·0 (3 minutes)	120·0 (3 minutes)	167·0 (3 minutes)
Remarks	Turbid, with only a small amount of dark-brown sediment. Earthy smell. Alkaline.	Turbid, with a small quantity of dark-brown suspended matter (slightly more than in 453). Not offensive, though fairly strong smell. Alkaline.	Turbid, with rather more brown sediment than No. 254. Suspicious but not distinctly sewage smell. Alkaline.

SOUTH NORWOOD SEWAGE FARM, 1902.

Hourly Sewage Samples drawn in Equal Quantities per Hour.

456 Screened and Settled Sewage. 24 Hours' Sample.	457 Screened and Settled Sewage. 24 Hours' Sample.	458 Screened and Settled Sewage. 24 Hours' Sample.	459 Screened and Settled Sewage. 24 Hours' Sample.
Inches. 0·0	Inches. 0·0	Inches. 0·0	Inches. 0·0
From Thursday, 16th January 1902, 5 p.m., to 17th January, 4 p.m.	From Friday, 17th January 1902, 5 p.m., to 18th January, 4 p.m.	From Saturday, 18th January 1902, 5 p.m., to 19th January, 4 p.m.	From Sunday, 19th January 1902, 5 p.m., to 20th January, 4 p.m.
18th January 1902.	20th January 1902.	21st January 1902.	22nd January 1902.
3·22	3·42	3·45	3·84
0·87	0·55	1·04	0·57
Trace.	Trace.	None.	None.
0·30	0·02	0·05	0·14
5·42	4·46	5·26	5·30
(0·45 in 4·43)	(0·54 in 3·79)	(0·54 in 4·38)	(0·45 in 4·34)
1·03	0·47	0·72	0·75
1·90	1·02	1·76	1·32
2·22	1·02	2·01	1·49
8·58	5·43	8·33	5·74
——	3·21 } 7 days.	6·31 } 6 days.	——
——	5·50	10·97	——
——	Putrid.	Putrid; sulphides.	——
7·62	7·42	8·00	7·14
106·6 { 39·7 volatile 66·9 non-volatile	87·4 { 23·4 volatile 64·0 non-volatile	105·2 { 36·8 volatile 68·4 non-volatile	79·5 { 29·1 volatile 50·4 non-volatile
38·2 { 21·4 volatile 16·8 non-volatile	11·4 { 6·6 volatile 4·8 non-volatile	32·2 { 18·4 volatile 13·8 non-volatile	9·6 { 7·2 volatile 2·4 non-volatile
68·4 { 18·3 volatile 50·1 non-volatile	76·0 { 16·8 volatile 59·2 non-volatile	73·0 { 18·4 volatile 54·6 non-volatile	69·9 { 21·9 volatile 48·0 non-volatile
12·84	2·80	7·56	5·20
——	——	——	——
4·76	1·52	5·48	1·72
——	——	——	——
181·0 (3 minutes)	80·0 (3 minutes)	245·0 (3 minutes)	87·0 (3 minutes)
Brown and turbid, with a small amount of dark-grey sediment. Soapy smell. Alkaline.	Apparently weaker than previous samples. Small amount of light-brown sediment. Clean smell. Alkaline.	*Apparently* as dilute as the last sample, with a small amount of dark-brown sediment. Faint sewage smell. Alkaline.	Turbid and brownish, with *apparently* a fair amount of flocculent sediment (light brown in colour). Faint sewage smell. Alkaline.

SOUTH NORWOOD SEWAGE FARM, 1900.

Sewage with Effluents.

No. of Sample	21	22	23
Nature of Sample	Screened and Settled Sewage.	First Field Effluent (over one plot of Rye Grass).	Final Effluent (over three separate Rye Grass plots).
Drawn	Tuesday, 9th January 1900, 2.15 p.m.	Tuesday, 9th January 1900, 3.15 p.m.	Tuesday, 9th January 1900, 5.15 p.m.
Temperature of sample	7·8° C. (46° F.)	6·1° C. (43° F.)	4·4° C. (40° F.)
Temperature of air	——	——	——
If jointed or incubated	——	——	——
Analysed	11th January 1900.	11th January 1900.	10th January 1900.
Parts per 100,000, *by weight.*			
Ammoniacal nitrogen (a) by direct Nesslerization.	Turbid.	Turbid	Turbid.
Ammoniacal nitrogen (b) by distillation.	——	——	——
Albuminoid nitrogen	——	——	——
Nitrous nitrogen	0·51	0·45	0·13
Nitric nitrogen	——	——	——
Total nitrogen, by Kjeldahl, *with* reduction (after correction for nitrite).	3·52	2·96	2·83
Blank	(0·28 in 5·51)	(0·41 in 4·84)	(0·28 in 4·71)
Correction for nitrite	+ 0·26	+ 0·20	+ 0·07
"X" nitrogen	——	——	——
Organic nitrogen by Kjeldahl, *with* reduction.	——	——	——
Organic nitrogen by Kjeldahl, *without* reduction.	——	——	——
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once*	1·61	1·27	0·42
" " " *after four hours*	6·74	3·21	0·71
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once*	——	0·45	0·36
" " " *after four hours*	——	1·83	1·55
Smell after incubation	——	Not noted, but presumably sweet.	Distinct putrefactive smell, but no blackening.
Chlorine	7·84	7·64	7·28
Gases: parts per 1,000, *by volume.*			11th January.
Carbon dioxide (free)	——	35·60	31·50
Oxygen (boiled out)	——	0·42	1·73
Nitrogen	——	19·08	18·64
Remarks	Sewage weak from recent rains. It apparently contained some laundry refuse.	This effluent was turbid, with a good deal of flocculent matter. Rather strong earthy and fishy smell. Slightly alkaline. A great deal of lime and much sulphate in solution.	Turbid, though there was not much flocculent matter. A kind of fishy smell. Slightly alkaline. A great deal of lime and much sulphate in solution.

SOUTH NORWOOD SEWAGE FARM, 1900.

Sewage with Effluents.

24 Screened and Settled Sewage.	25 First Field Effluent off Rye Grass Field, No. 45. (Sewaged since 14th inst.).	26 Final, *i.e.*, Second Field Effluent off Rye Grass Field, No. 44.	27 Another First Field Effluent off arable ploughed Field (this was also drawn to correspond with Sewage No. 24).
Tuesday, 16th January 1900, 1 p.m.	Tuesday, 16th January 1900, 2 p.m.	Tuesday, 16th January 1900, 3 p.m.	Tuesday, 16th January 1900, 2.45 p.m.
7·8° C. (46° F.)	6·7° C. (44° F.)	5·0° C. (41° F.)	6·7° C. (44° F.)
—	—	—	—
—	—	—	—
17th January 1900.	19th January 1900.	18th January 1900.	17th January 1900.
Turbid.	Turbid.	Turbid.	Turbid.
—	—	—	—
—	—	—	—
0·04	0·19	0·01	0·06
—	—	—	—
4·62	2·92	2·36	3·40
(0·41 in 7·80)	(0·28 in 4·80)	(0·28 in 4·05)	(0·28 in 5·69)
+ 0·02	+ 0·10	+ 0·01	+ 0·03
—	—	—	—
—	—	—	—
—	—	—	—
1·30	0·60	0·13	0·82
7·97	2·23	0·97	4·45
—	0·79	0·44	1·60
—	2·02	1·33	3·57
—	Putrid, with smell of ammonium sulphide. No blackening.	No appreciable smell.	Slight blackening, with a smell of sulphuretted hydrogen.
7·60	6·62	6·42	6·62
—	29·44	21·38	25·73
—	0·60	5·19	2·56
—	20·37	16·63	17·28
This was evidently very dilute. It contained a moderate amount of light brown sediment. Soapy (not sewage) smell. Faintly alkaline.	Turbid, with a good deal of flocculent matter. Fishy smell. Distinctly alkaline. A great deal of lime and much sulphate in solution.	Opalescent, with a *very little* flocculent maettr. Clean earthy smell. Distinctly alkaline. A great deal of lime and much sulphate.	Very turbid, with much grey flocculent matter. Soapy smell; slightly alkaline. A great deal of lime and much sulphate.

SOUTH NORWOOD SEWAGE FARM, 1900.

Sewage and Effluent.

No. of Sample	28	29
Nature of Sample	Screened and Settled Sewage.	Second Field Effluent.
Drawn	Monday, 22nd January 1900, 2.30 p.m.	Monday, 22nd January 1900, 4 p.m.
Temperature of sample	7·8° C. (46° F.)	6·7° C. (44° F.)
Temperature of air	—	—
If jointed or incubated	—	—
Analysed	23rd January 1900.	24th January 1900.
Parts per 100,000, *by weight.*		
Ammonical nitrogen:		
(a) By direct Nesslerization	Turbid.	Turbid.
(b) By distillation	—	—
Albuminoid nitrogen	—	—
Nitrous nitrogen	0·12	0·04
Nitric nitrogen	—	—
Total nitrogen by Kjeldahl, *with* reduction (after correction for nitrite).	5·16	2·36
Blank	(0·59 in 8·77)	(0·44 in 4·20)
Correction for nitrite	+ 0·06	+ 0·02
"X" nitrogen	—	—
Organic nitrogen by Kjeldahl, *with* reduction.	—	—
Organic nitrogen by Kjeldahl, *without* reduction.	—	—
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once.*	1·60	0·28
" " " , *after four hours*	8·18	1·57
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once*	—	0·31
" " " " *after four hours*	—	1·38
Smell after incubation	—	Clean, earthy.
Chlorine	8·28	7·10
Gases: parts per 1,000, *by volume.*		
Carbon dioxide (free)	—	29·87
Oxygen (boiled out)	—	0·85
Nitrogen	—	17·51
Remarks	Light-brown and grey deposit. Soapy and very slight sewage smell. Alkaline.	Opalescent and distinctly brown, but with hardly any flocculent matter. Earthy smell. Very distinctly alkaline. A great deal of lime and a moderate amount of sulphate in solution.

SOUTH NORWOOD SEWAGE FARM, 1900.

Effluents.

30 Third Field Effluent.	31 General Final Effluent.	35 General Final Effluent.
Monday, 22nd January 1900, 4.45 p.m.	Tuesday, 30th January 1900, 4 p.m.	Monday, 29th January 1900, 3.30 p.m.
7·2° C. (45° F.)	3·3° C. (38° F.)	3·3° C. (38° F.)
——	——	——
——	——	——
23rd January 1900.	31st January 1900.	30th January 1900.
Turbid.	Turbid.	Turbid.
——	——	——
——	——	——
0·04	0·02	0·03
——	——	——
2·64	2·47	2·65
(0·28 in 4·48)	(0·44 in 4·39)	(0·59 in 4·81)
+ 0·02	+ 0·01	+ 0·02
——	——	——
——	——	——
——	——	——
0·40	0·29	0·29
1·68	1·30	1·71
0·41 } Six days. 1·54 }	0·50 1·57	0·45 } Six days. 1·33 }
Earthy.	Doubtful.	Faint sewage smell
7·14	7·54	7·10
		(a) 11.30 a.m. / (b) 2.30 p.m.
27·11	27·21	23·92 / 24·37
3·19	5·42	6·05 / 5·98
17·26	17·91	17·85 / 17·76
Opalescent and brownish, but containing very little flocculent matter. This looked a better effluent than the previous ones. Earthy smell. Distinctly alkaline.	This contained an appreciable amount of brownish flocculent matter in rather small particles. Earthy smell. Slowly alkaline. A great deal of lime and a good deal of sulphate.	(a) Sucked into apparatus from sample bottle. (b) Transferred at 11.30 a.m. to 250 c.c. flask, which was filled completely and stoppered. This contained a moderate amount of brownish flocculent matter. Earthy-fishy smell. Slowly alkaline. A great deal of lime and a good deal of sulphate.

SOUTH NORWOOD SEWAGE FARM, 1900.

Sewage and Effluents.

No. of Sample	170		170.(1)	171		175
Nature of Sample	Crude Sewage.		Artificial Storm Water.	Final Effluent over two plots of Rye Grass, corresponding to Sewage No. 170.		Final Effluent over four plots of Rye Grass.
Drawn	Wednesday, 7th November 1900, 12 noon.			Wednesday, 7th November 1900, 2.30 p.m.		Tuesday, 14th November 1900, 2·45 p.m.
Temperature of sample	12·8° C. (55° F.)			10·0° C. (50° F.)		8·9° C. (48° F.)
Temperature of air	10·0° C. (50° F.)			9·4° C. (49° F.)		10·6° C. (51° F.)
If jointed or incubated	——			——		——
Analysed	8th November 1900.			8th November 1900.		15th November 1900.
Parts per 100,000, *by weight.*	(A)	(B)		(A)	(B)	
	Same bottle.			Same bottle.		
Ammoniacal nitrogen: (a) by direct Nesslerization	—		Sewage made down to *half* the Mersey and Irwell Standard on the albuminoid nitrogen, *i.e.*, containing 0·06 part albuminoid nitrogen per 100,000. It was made from 20 c.c. sewage, No. 170, and 336 c.c. tap water. Portion (a) was kept in a small (full) bottle at atmospheric temperature, while (b) was incubated at 80° F., until 14th November.	— (approx.; turbid)	0·14	1·97
(b) by Distillation	5·14	5·56		0·02	0·014	1·55
Albuminoid nitrogen	1·05	0·92		0·09	0·09	0·13
Nitrous nitrogen	None.	None.		None.	None.	None.
Nitric nitrogen	Not done.	Not done.		0·29	0·31	0·14
Total nitrogen by Kjeldahl, *with* reduction (after correction for nitrite).	No sugar 7·52	7·25		No sugar 0·49	0·60	(a) 2·14 (b) 2·13
Blank	(0·12 in 5·49.)	(0·13 in 5·45.)		(0·12 in 0·82)	0·13 in 1·01)	(0·13 in 3·26)
Correction for nitrite	None.	None.		None.	None.	None.
"X" nitrogen	1·33	0·77		0·09	0·19	0·32
Organic nitrogen by Kjeldahl, *with* reduction.	2·38	1·69		0·18	0·28	0·45
Organic nitrogen by Kjeldahl, *without* reduction: (a) Taking ammonia by direct Nesslerization.	—	—	——	—	Finished 27 Nov. 0·14	none (—·35)
(b) Taking ammonia by distillation	—	—	8 Nov. 14 Nov. (a) (b)	—	0·14	0·07 Finished 23rd Nov.
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once.*	2·70	2·57	0·24 0·24 0·24	0·46	0·45	0·43
" " " *after four hours*	12·94	Lost	——	1·87	1·47	1·33
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once*	—	—	——	—	0·29	0·52 One day, by mistake.
" " " *after four hours*	—	—	(a) was *just* putrid.	—	1·54	1·54
Smell after incubation	—	—	(b) was *very* putrid.	— Clean, earthy.		Sweet.
Chlorine	8·96	8·80	——	—	6·66	——
Gases: parts per 1,000, *by volume.*						
Oxygen (by cuprous chloride)*: (a) When sample was drawn		—	— —	3·0		3·0
(b) " " " analysed	—	—	— —	about 4·0; about 3·0; 3·1 Three observers. *Note.*—The standards had deteriorated.		1·0 to 1·5 Less than 2·0 About 1·0 Three observers.
Remarks	Contained only a small amount of rather flocculent deposit. Sewage smell. Alkaline.		——	This sample was of a rather deep lemon colour, and contained a small but appreciable amount of light-brown flocculent matter.		Lemon-coloured, with a small amount of red-brown flocculent matter. Smell slightly fishy-earthy.

**Note.*—As the South Norwood effluents had a lemon to brown tinge, the figures for oxygen obtained with cuprous chloride are almost certainly too low.

SOUTH NORWOOD SEWAGE FARM, 1900.

Sewage and Effluents.

176 Screened nd Settled Sewage.	177 First Field Effluent.	178 Final Effluent.	178 Small Duplicate.	180 Final Effluent off Rye Grass.	180a Final Effluent over three plots of Rye Grass (small sample).	184 General Effluent.
esday, 20th ovember 1900, 2 noon.	Tuesday 20th November 1900, 2 p.m.	Tuesday, 20th November 1900, 3 p.m.	—	Wednesday, 21st November 1900, 1.45 p.m.	Friday, 23rd November 1900, 1.15 p.m.	Wednesday, 28th November 1900, 2.15 p.m.
·1° C. (52° F.)	9·4° C. (49° F.)	6·7° C. (44° F.)	—	7·2° C. (45° F.)	6·7° C. (44° F.)	7·8° C. (46° F.)
·7° C. (44° F.)	7·2° C. (45° F.)	7·2° C. (45° F.)	—	7·8° C. (46° F.)	7·2° C. (45° F.)	9·4° C. (49° F.)
—	—	—	Jointed and incubated, 21st November. On top of incubator part of time.	—	Jointed and incubated 24th November, partly on top of incubator.	—
st Nov. 1900.	21st Nov. 1900.	22nd November 1900.	6th December 1900.	23rd November 1900.	7th December 1900.	29th Nov. 1900.
	(B) (A)	(A) (B) Same bottle, no doubt.				
—	Turbid —	— 0·87 (approx.; turbid)	—	Turbid.	—	1·07 (slightly turbid.)
6·80	4·92 5·27	0·68 0·71	0·62	1·20	0·82	0·95
1·10	0·56 0·62	0·07 0·06	0·07	0·08	0·10	0·14
None.	None	0·01 0·01	1·03	Very slight trace.	0·30	0·01
Not done.	Not done.	0·73 1·08 (not reliable).		0·21		0·65
9·52	6·79	1·82 1·88	—	No sugar 1·69 Sugar 1·78	—	2·05
(0·12 in 6·92)	(0·13 in 10·10)	(0·12 in 2·71) (0·13 in 2·87)	—	(0·12 in 2·54) (0·12 in 2·66)	—	(0·13 in 3·12)
None.	None.	+ ·01 + ·01	—	None.	—	+ 0·01
1·62	1·31	0·33 ?	—	0·20 0·29	—	0·30
2·72	1·87	0·40 ?	—	0·28 0·37	—	0·44
—	—	Finished about a week later.	—	—	Finished within a fortnight. Probably a little high. Rather turbid.	—
—	1·21	0·25 0·17	—	0·34 Finished Dec. 5th.	0·46	—
2·78	1·04	0·40 0·42	0·21	0·24	0·12	0·37
14·26	7·90	1·19 1·21	—	1·01	—	1·73
—	—	0·28 0·28	—	0·37	—	0·43
—	—	1·19 1·07	—	1·14	—	1·59
—	—	Sweet or Doubtful? Sweet.	No smell.	Putrid Sweet Two observers. (Probably putrid.)	Sweet.	Strong, earthy.
7·42	7·68	— 7·90	—	6·90	—	
—	—	2·0*	—	2·0	—	0·5
—	—	About 5·75*	Mere trace, if any.	About 1·0 Very green and difficult to read. Standards deteriorated.	—	1·0 or less 1.3 1·0 Three observers. Very dim and difficult to read.
nsiderable rown sediment; ne liquid por- on smelt rongly of pep- ermint. Alka- ne.	Turbid, distinctly yellow liquid, but otherwise not much sediment. Strong sewage smell. Alkaline. (The sample had a strong sewage smell when drawn.)	This looked a good effluent, clear, with a slight lemon tinge, and but a small amount of light-brown flocculent matter. Clean, slightly fishy-earthy smell. * Cannot explain this discrepancy.	This incubated sample was practically clear and colourless. Very little light brown sediment.	This looked an excellent effluent, slightly brown coloured, and with little more than a trace of brown flocculent matter. Clean fishy-earthy smell.	This incubated liquid contained several black specks, and one or two good-sized brownish aggregates; also a dead fly.	This sample was dim and opalescent, with a distinct brownish tinge, and contained an appreciable amount of brown flocculent matter. Fishy-earthy smell.

SOUTH NORWOOD SEWAGE FARM, 1900.

(Special Experiment.)

No. of Sample	181a	181a (2)	181a (3)	181a (4)
Nature of Sample	Screened and Settled Sewage	Artificial Storm Water Made to Mersey and Irwell standard on the albuminoid nitrogen, from No. 181a., *i.e.*, 100 c.c. sewage and 944 c.c. tap water. Mixed, 28th November, and a portion incubated.*	The same mixture as in No. 181a (2), but containing 0·1 part nitric nitrogen per 100,000, added as potassic nitrate, KNO_3. Incubated* 28th November.	The same mixture as No. 181a (2), but containing 0·2 part nitric nitrogen per 100,000, added as KNO_3. Incubated,* 28th November.
Drawn	Tuesday, 27th November 1900, 1 p.m.			
Temperature of sample	11·1° C. (52° F.)			
Temperature of air	10·6° C. (51° F.)			
If jointed or incubated	—			—
Analysed	28th November 1900.	10th December.	10th December.	10th December.
Parts per 100,000, *by weight.*				
Ammoniacal nitrogen (a) by direct Nesslerization.	—	—	—	—
Ammoniacal nitrogen (b) by distillation.	7·60	—	—	—
Albuminoid nitrogen	1·23	—	—	—
Nitrous nitrogen	None.	—	—	0·05 †
Nitric nitrogen	Not done.			
Total nitrogen by Kjeldahl, *with* reduction (after correction for nitrite).	10·84	—	—	—
Blank	(0·12 in 7·86)	—	—	—
Correction for nitrite	None.	—	—	—
"X" nitrogen	2·01	—	—	—
Organic nitrogen, by Kjeldahl, *with* reduction.	3·24	—	—	—
Organic nitrogen, by Kjeldahl, *without* reduction: Taking ammonia by distillation	—	—	—	—
		Before incubation. 28th Nov. / After incubation. 10th Dec.	10th December	10th December.
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once.*	2·60	0·19 / 1·20	1·07	0·65
" " " *after four hours*	20·08	—	—	—
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once.*	—	—	—	—
" " " *after four hours*	—	—	—	—
Smell after incubation	—	Very putrid.	Very putrid.	Very putrid.
Chlorine	7·80	—	—	—
Gases: parts per 1000, *by volume.*				
Oxygen (by cuprous chloride): (a) When sample was drawn	—	—	—	—
(b) " " analysed	—	—	—	—
Remarks	Mr. Kershaw noted on label that there were fairly strong soapsuds coming down in this sample. Aggegated brown sediment. Sour smell. Alkaline.	*Notes.*—1. * On top of incubator from 28th November to incubator from 5th December to 10th December. 2. † There is, of course, great difficulty in estimating nitrate in mixtures like these, with certainty. 3. The above results show that the nitrate corresponding gen per 100,000, in addition to the oxygen contained in is insufficient to keep a dilute (domestic) sewage, yielding trogen per 100,000, from becoming putrid upon incubation. (The tap water also contained a little nitrate, in addition to cf. page 322, *Note.*)		

SOUTH NORWOOD SEWAGE FARM, 1900.

(Special Experiment.)

181a (5)	181	181	183	183
The same mixture as No 181a (2), but containing 0·3 part nitric nitrogen per 100,000, added as KNO_3. Incubated* 28th November.	SURFACE EFFLUENT from 1st arable field.	SMALL DUPLICATE.	SURFACE EFFLUENT from 1st arable field.	SMALL DUPLICATE.
	Tuesday, 27th November 1900, 2.15 p.m.	—	Wednesday, 28th November 1900, 1.30 p.m.	—
	8·9° C. (48° F.)	—	7·8° C. (46° F.)	—
	12·2° C. (54° F.)	—	8·9° C. (48° F.)	—
—	—	Jointed and incubated, 28th November (partly on top of incubator).	—	Jointed and incubated, 29th November (partly on top of incubator).
10th December.	28th November 1900.	7th December 1900.	29th November 1900.	13th December 1900.
—	—	—	Turbid.	—
—	0·32	0·34	0·43	0·51
—	0·18 {This dribbled over.}	0·18 {Dribbled over.}	0·22	0·19
0·10 †	0·14	0·13	0·32	7·37
	10·49	10·19	8·11	
—	11·82	—	No sugar. 9·38 Sugar. 9.36	—
—	(0·13 in 17·36)	—	(0·12 in 13·18 and 0·15 in 13·28)	—
—	+0·07	—	+ 0·16	—
—	0·69	—	0·30 0·28	—
—	0·87	—	0·52 0·50	—
—	—	—	0·31	—
10th December. 0·92	0·42	—	0·58	0·60
—	1·80	—	2·09	—
—	0·42	—	0·74	—
—	1·53	—	2·35	—
Very putrid.	Doubtful, but not bad.	Slight mustard smell, but quite good.	Earthy; Doubtful. {Two observers.}	Earthy and rather musty.
—	11·20	—	9·68	—
—	1·0 (?)	—	—	—
—	{3 to 4 c.c. About 3·0 About 3·0 } Three observers. Very hard to read.	None.	{1·0 a little under 1·0} Two observers. Very dim and difficult to read.	—
5th December. Inside such small amounts of to 0·3 part nitric nitro- 9½ volumes of tap water, 0·12 part albuminoid ni- its dissolved oxygen;	Very muddy, with a large amount of light brown sediment. Clean earthy smell. Mr. Kershaw wrote: "This effluent comes from what had *filtered* through the soil into the pick-up carrier at the bottom of the plot; the top water had not reached the bottom of the first plot. The effluent comes through the soil in most curious places, owing, no doubt, to the presence of small cracks."	*Note.*—The above ammonia estimations were probably slightly affected by a little sediment at the bottom of the bottle not being detached until the test for dissolved oxygen was made.	Opalescent, with distinct brownish tinge, but no suspended matter. Clean smell (slightly fishy-earthy).	Very slight sediment.

SOUTH NORWOOD SEWAGE FARM, 1900.

(Special Experiment—*continued.*)

No of Sample	No. 185a	185	185	186a
Nature of Sample	Surface Effluent, off First Arable Field.	Final Surface Effluent, off Second Arable Field.	Small Duplicate.	Surface Effluent, off First Arable Field. (Small Sample.)
Drawn	Thursday, 29th Nov. 1900, 1 p.m.	Thursday, 29th Nov. 1900, 2.15 p.m.	—	Friday, 30th Nov. 1900, 11.30 a.m.
Temperature of sample	7·8° C. (46° F.)	7·2° C. (45° F.)	—	7·8° C. (46° F.)
Temperature of air	8·3° C. (47° F.)	8·3° C. (47° F.)		8·3° C. (47° F.)
If jointed or incubated	—	—	Jointed and incubated, 30th Nov., partly on top of incubator.	—
Analysed	30th Nov. 1900.	30th Nov. 1900.	11th Dec. 1900.	15th Dec. 1900.
Parts per 100,000, *by weight.*				
Ammoniacal nitrogen (a) by direct Nesslerization.	—	Turbid.	—	—
Ammoniacal nitrogen (b) by distillation.	0·28	0·06	—	0·54
Albuminoid nitrogen	0·22	0·21	—	0·17
Nitrous nitrogen	0·31	0·07	1·73	4·69
Nitric nitrogen	8·69	1·79		
Total nitrogen by Kjeldahl, *with* reduction (after correction for nitrite).	Without Sugar. 10·32; With Sugar. 10·11	2·29	—	—
Blank	(0·15 in 14·66 and in 14·36)	(0·13 in 3·44)	—	—
Correction for nitrite	+0·16	+0 03	—	—
"X" nitrogen	0·82 0·61	0·16	—	—
Organic nitrogen by Kjeldahl, *with* reduction.	1·04 0·83	0·37	—	—
Organic nitrogen by Kjeldahl, *without* reduction:				
(b) Taking ammonia by distillation	0·31	0·15 (No oxalate. Nesslerized 13th Dec.)	—	—
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once.*	0·50	0·21	—	0·33
" " " *after four hours*	2·32	1·58	—	—
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once*	0·52	0·49	—	—
" " " *after four hours*	2·08	1·43	—	—
Smell after incubation	Strong earthy; Just putrid. Two observers	Clean earthy.	Sweet.	Earthy.
Chlorine	9·24	16·40	—	—
Gases: parts per 1,000, *by volume.*				
Oxygen (by cuprous chloride):				
(a) When sample was drawn	2·0	4·0	—	3·0
(b) " " analysed	1·0, 1·3, 0·75 Three observers	About 3·0, " 3·75, " 3·9 Three observers	None.	—
	Very turbid and greenish to read.	This was blue, but dim to read.		
Remarks	This effluent was decidedly turbid and lemon-coloured, but otherwise had no appreciable sediment. Clean earthy smell.	This effluent, though a little turbid, contained really very little suspended matter. Clean earthy smell.	This incubated sample was clear, but distinctly brown, with a small amount of brown-red sediment. Sweet smell.	This sample after incubation contained only a very slight sediment. When drawn, it was fairly clear, with no smell.

SOUTH NORWOOD SEWAGE FARM, 1900.

(Special Experiment—*continued.*)

186 Second Field Surface Effluent.	187b Effluent, off First Arable Field (rain).	187c Second Field Effluent (rain).	187d Effluent off First Arable Field.	187 Second Field Effluent.
Friday, 30th Nov. 1900, 11.45 a.m.	Saturday, 1st Dec. 1900, 11.30 a.m.	Saturday, 1st Dec. 1900, 1.30 p.m.	Monday, 3rd Dec. 1900, 11.45 a.m.	Monday, 3rd Dec. 1900, 12 noon.
7·2° C. (45° F.)	7·8° C. (46° F.)	6·6° C. (44° F.)	7·2° C. (45° F.)	6·7° C. (44° F.)
8·3° C. (47° F.)	8·3° C. (47° F.)	8·3° C. (47° F.)	6·7° C. (44° F.)	6·7° C. (44° F.)
—	—	—	Jointed and incubated, 4th Dec., partly on top of incubator.	—
1st Dec. 1900.	3rd Dec. 1900.	3rd Dec. 1900.	18th Dec. 1900.	4th Dec. 1900.
Turbid.	—	Turbid.	—	Not noted
0·07	0·33	0·12	1·04	0·10
(1) 0·12	0·20	0·11	0·14	0·17
0·09	0·23	0·11	0·25	0·07
2·98	8·13 (2)	2·11	3·14	6·58
3·21	Without Sugar. 8·13; With Sugar. 8·08	2·60	—	8·04
(0·13 in 4·77)	(0·15 in 11·58 and 11·51)	(0·14 in 3·86)	—	(0·14 in 11·92)
+0·04	+ 0·12	+ 0·06	—	+0·03
None (–0·05)	?	0·15	—	1·12
0·12	?	0·26	—	1·29
0·07 No oxalate. Nesslerized 11th Dec.	—	0·17 No oxalate. 13th Dec.	—	0·19 1st Jan.
0·40	0·53	0·35	0·37	0·50
Not done.	2·12	1·50	—	2·08
0·35, 1·68 Six days.	0·27, 1·60 Seven days.	0·48, 1·58	—, —	0·49, 1·88 Six days.
Sweet.	Earthy, quite sweet.	Not exactly sweet, but not putrid.	Earthy.	Sweet.
16·80	8·44	15·90	—	13·42
1·0	—	—	Less than 1·0	0·5
Little more than a trace.	None.	Trace.	—	Trace, *i.e.* about 0·2.
This looked a very fair effluent. It was nearly clear, had a slight lemon colour, and there was very little sediment in it. Clean earthy smell. *N.B.*—A few floating seeds were rejected. (1) *Note.*—Too dark a day to Nesslerize, so this distillate was kept over till Monday.	Opalescent and decidedly yellow, but containing hardly any sediment. Earthy smell. (2) This nitrate estimation must be too high; it was done on 10 c.c.	Clear, and containing only a trace of darkish flocculent matter, also some floating seeds (rejected). Earthy smell.	This was brownish and clear (sediment not noted, evidently not appreciable). When drawn it had a very slight smell.	This was appreciably turbid, with an appreciable amount of dark sediment; also some seeds, which were removed as far as possible. Clean, slightly fishy-earthy smell.

SOUTH NORWOOD SEWAGE FARM, 1900–1.

(Special Experiment—*continued.*)

No. of Sample	188a	188	189a
Nature of Sample	First Arable Field Effluent.	Second Arable Field Effluent (weather, abnormally warm ; rain).	First Arable Field Effluent.
Drawn	Wednesday, 5th December 1900, 11.30 a.m.	Wednesday, 5th December 1900, 12.45 noon.	Friday, 7th December 1900, 11 a.m.
Temperature of sample	9·4° C. (49° F.)	9·4 (49° F.)	8·3° C. (47° F.)
Temperature of air	15·6° C. (60° F.)	15·6 (60° F.)	9·4° C. (49° F.)
If jointed or incubated	Jointed and incubated 6th December, partly on top of incubator.	——	Jointed and incubated 8th December, partly on top of incubator.
Analysed	19th December 1900.	6th December 1900.	20th December 1900.
Parts per 100,000, *by weight.*			
Ammoniacal nitrogen :			
(a) by direct Nesslerization	——	Turbid.	——
(b) by distillation	1·09	0·19	1·51
Albuminoid nitrogen	0·13	0·18	0·13
Nitrous nitrogen	0·13	0·08	0·08
Nitric nitrogen	1·10	5·43	0·09
Total nitrogen, by Kjeldahl, *with* reduction (after correction for nitrite).	——	Without sugar. 6·88 / With sugar. 6·92	——
Blank	——	(0·15 in 9·92 and in 9·98).	——
Correction for nitrite	——	+0·04	——
"X" nitrogen	——	0·90 / 0·94	——
Organic nitrogen, by Kjeldahl, *with* reduction.	——	1·08 / 1·12	——
Organic nitrogen, by Kjeldahl, *without* reduction :			
Taking ammonia by distillation	——	0·30 (a little turbid, so probably rather high).	——
Oxygen absorbed from permanganate at 26·7° C. (80° F.) ; *at once.*	0·54	0·33	0·21
,, ,, ,, *after four hours*	——	2·24	——
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.) ; *at once*	——	0·54 } Seven days.	——
,, ,, ,, *after four hours*	——	1·96 } Seven days.	——
Smell after incubation	Earthy.	Sweet ; earthy.	Earthy.
Chlorine	——	10·16	——
Gases : parts per 1,000, *by volume.*			
Oxygen (by cuprous chloride) :			
(a) When sample was drawn	——	——	0·25
(b) ,, ,, ,, analysed	——	None.	——
Remarks	When drawn this had a slight sewage smell. After incubation it showed a considerable brown sediment, rather aggregated. Earthy smell. Alkaline.	This was dim, but with only very little brownish flocculent matter. Lemon colour. Clean, fishy-earthy smell. An exceptionally large quantity of lime in solution and also much sulphate, but only a trace of iron.	When drawn this effluent was cloudy, with a distinct sewage smell. After incubation it was practically colourless, slightly turbid, and with a small amount of grey-brown sediment. Earthy smell.

SOUTH NORWOOD SEWAGE FARM, 1900–1.

(Special Experiment—*continued.*)

189 Second Arable Field Effluent (diluted by rain).	189 Large Duplicate.	189b First Arable Field Effluent.	189c Second Arable Field Effluent.	190 First Arable Field Effluent.	191 Second Arable Field Effluent.
Friday, 7th December 1900, 12·30 noon.	—	Saturday, 8th December 1900, 11 a.m.	Saturday, 8th December 1900, 12·40 noon.	Monday, 10th December 1900, 12 noon.	Monday, 10th December 1900, 1.30 p.m.
—	—	8·9° C. (48° F.)	8·3° C. (47° F.)	7·8° C. (46° F.)	6·7° C. (44° F.)
—	—	10·6° C. (51° F.)	11·1° C. (52° F.)	9·4° C. (49° F.)	10·0° C (50° F.)
—	Jointed 8th Dec. (weather warm).	Jointed and incubated 10th Dec., partly outside incubator.	—	Jointed and incubated 11th Dec., mostly inside incubator.	—
8th December 1900.	4th January 1901.	31st Dec. 1900.	10th December 1900.	1st January 1901.	12th Dec. 1900.
Turbid.	—	—	Turbid.	—	Turbid.
0·19	0·25	1·32	0·30	—	0·20
0·13	0·17	0·21	0·17	—	0·13
0·06	0·10	0·02 (approx.)	0·06	None.	0·11
4·43 (possibly too low).	4·63	0·64	5·29		4·68
5·93	5·75	—	Without sugar. 6·26 With sugar. 6·22	—	5·52
(0·14 in 8·80)	(0·14 in 8·48)	—	(0·15 in 9·05 and in 8·99)	—	(0·14 in 8·14)
+0·03	+0·05	—	+0·03	—	+0·06
1·12 } possibly too high.	0·60	—	0·44 0·40	—	0·40
1·28 } possibly too high.	0·77	—	0·61 0·57	—	0·53
None. (−0·07)	None. (−0·01)	0·78 (approx.)	0·24 (Very approximate. Very turbid).	—	0·10
0·36	0·55	0·45	0·43	12·87	0·34
—	1·65	—	2·11	—	1·99
0·21	0·51	—	0·43	—	0·34
1·58	1·61	—	1·86	—	1·66
Sweet.	Sweet; earthy.	Earthy.	Sweet.	—	Sweet.
10·80	—	—	9·54	—	10·50
1·75	—	Mere trace.	2·0	—	1·5
Not more than 0·5 on 8th December (two observers). Excessively green, and difficult to read.	None, or merest trace.	—	0·5 } On 10th Dec., 0·75 } (two observers.) Very green to read.	—	Less than 1·0 on 12th December. Very green and difficult to read.
When drawn this had a very slight smell. On 8th December it was nearly clear, with practically no suspended matter. Clean smell, but decidedly fishy-earthy. An enormous amount of lime and much sulphate in solution; no iron, or practically none.	Slightly lemon-coloured, and with a small amount of very flocculent brown organic matter; otherwise quite clear. Clean smell.	When drawn this effluent had a strong sewage smell. After incubation it was brownish, with very slight sediment. Earthy smell.	When drawn this had a slight sewage smell on shaking. On 10th December it was clear, bright lemon-yellow in colour, and with only a very small quantity of brown flocculent matter. Clean earthy or slightly fishy-earthy smell.	When drawn this had a sewage smell. After incubation there was a considerable amount of black sediment with a very offensive sulphuretted hydrogen odour.	Slight smell when drawn on 12th December. Lemon-coloured, but less so, I think, than No. 192. Trace of brownish flocculent matter. Clean, slightly fishy-earthy smell.

SOUTH NORWOOD SEWAGE FARM, 1900–1.

(Special Experiment—*continued*).

No. of Sample	191a	192	193
Nature of Sample	First Arable Field Effluent.	Second Arable Field Effluent.	First Arable Field Effluent.
Drawn	Tuesday, 11th December 1900, 11.20 a.m.	Tuesday, 11th December 1900, 1 p.m.	Thursday 13th December 1900, 12 noon.
Temperature of sample	8·3° C. (47°F.)	7·2° C. (45°F.)	9·4° C. (49° F.)
Temperature of air	9·4° C. (49°F.)	10·0° C. (50°F)	10·0° C. (50° F.)
If jointed or incubated	Jointed and incubated, 12th December, partly on top of incubator.	——	Jointed and incubated 14th December, partly on top of incubator.
Analysed	1st January 1901.	12th December 1900.	1st January 1901.
Parts per 100,000, *by weight.*			
Ammoniacal nitrogen : (a) by direct Nesslerization	——	Turbid.	——
(b) by distillation	0·77	0·19	1·06
Albuminoid nitrogen	0·12	0·18	0·16
Nitrous nitrogen	0·05	0·05	0·03
Nitric nitrogen	2·44	4·52	0·94
Total nitrogen, by Kjeldahl, *with* reduction (after correction for nitrite).	——	Without sugar. 5·61 / With sugar. 5·63	——
Blank	——	(0·15 in 8·12 and in 8·15)	——
Correction for nitrite	——	+0·03	——
"X" nitrogen	——	0·67 / 0·69	——
Organic nitrogen, by Kjeldahl, *with* reduction.	——	0·85 / 0·87	——
Organic nitrogen, by Kjeldahl, *without* reduction : Taking ammonia by distillation	——	0·24	0·61 (slightly turbid.)
Oxygen absorbed from permanganate at 26·7° C. (80° F.) ; *at once.*	0·30	0·31	0·47
,, ,, ,, *after four hours*	——	2·02	——
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80°F.) ; *at once*	——	0·28	——
,, ,, ,, *after four hours.*	——	1·86	——
Smell after incubation	——	Sweet.	Sweet.
Chlorine	——	10·30	——
Gases: parts per 1,000, *by volume.*			
Oxygen (by cuprous chloride) : (a) when sample was drawn	0·5	1·75	——
(b) ,, ,, ,, analysed	——	About 1·0 Very bright green and difficult to compare.	——
Remarks	When drawn, this effluent had a sewage smell. After incubation it was a clear yellow liquid, with a small amount of brown sediment. No smell.	When drawn, this had a very slight sewage smell. On 12th December it was clear and lemon coloured, with, one may say, no suspended matter. Clean, and slightly fishy – earthy smell.	This had a sewage smell when drawn. After incubation it showed a considerable aggregated brown sediment. Earthy smell. (Quite sweet.)

SOUTH NORWOOD SEWAGE FARM, 1900–1.

(Special Experiment—*continued*).

193a Settled Sewage (somewhat dilute.)	193a (1) Artificial Storm Water.	193a (2) Artificial Storm Water.	193a (3) Artificial Storm Water.	193a (4) Artificial Storm Water.
Wednesday, 12th December 1900, 11 a.m. 11·1° C. (52° F.) 10·0° C. (50° F.) — 14th December 1900.	Storm water made by diluting the foregoing sewage down to the Mersey and Irwell standard of albuminoid nitrogen on 14th December, *i.e.*, 100 c.c. sewage + 740 c.c. distilled water containing 6·25 c.c. oxygen per litre. Incubated; but no subsequent notes made.	The same artificial storm water + 0·3 part nitric nitrogen per 100,000, added as potassium nitrate, KNO_3, on 14th December. This was incubated on top of incubator till 19th December, and inside 19th to 20th. Analysed 20th December 1900.	The same artificial storm water + 0·15 part nitric nitrogen per 100,000, added as ammonium nitrate, NH_4NO_3, on 14th December. Incubated exactly like 193a (2). Analysed 20th December 1900.	The same artificial storm water as 193a (2), but diluted on 14th December with 3 vols. distilled water (this water contained 6·25 c.c. oxygen per litre.) Incubated like the others. Analysed 20th December 1900.
—				
6·24				
0·99				
Very slight trace.	—	0·128	0·128	Taken as KNO_3 0·075 — Found 0·055
Not done.	—			
8·43				
(0·15 in 6·17)				
None.				
1·20				
2·19				
—				
2·13				
9·66				
—				
—				
—	—	Earthy but sweet.	Earthy but sweet.	Sweet.
7·28				
—				
—	—	—	—	Taken 6·25 — Found 3·75
Moderate amount of brown sediment. Fairly strong sewage smell. Alkaline.				

SOUTH NORWOOD SEWAGE FARM, 1900–1.

(Special Experiment—*continued.*)

No. of Sample	194	194a	194b
Nature of Sample	Second Field Effluent.	First Field Effluent. (Small Sample.)	Second Arable Field Effluent.
Drawn	Thursday, 13th December 1900, 1 p.m.	Friday, 14th December 1900, 10.30 a.m.	Friday, 14th December 1900, 11.30 a.m.
Temperature of sample	10·0° C. (50° F.)	8·3° C. (47° F.)	6·1° C. (43° F.)
Temperature of air	10·6° C. (51° F.)	10·6° C. (51° F.)	10·6° C. (51° F.)
If jointed or incubated	——	Jointed and incubated, 15th December, partly on top of incubator.	——
Analysed	14th December 1900.	2nd January 1901.	15th December 1900.
Parts per 100,000, *by weight.*			
Ammoniacal nitrogen (a) by direct Nesslerization.	Turbid.	——	Turbid.
Ammoniacal nitrogen (b) by distillation.	0·26	1·30	0·37
Albuminoid nitrogen	0·17	0·13	0·14
Nitrous nitrogen	0·02	Mere trace.	0·03
Nitric nitrogen	4·02	0·80	3·11
Total nitrogen by Kjeldahl, *with* reduction (after correcting for nitrite).	4·63	——	3·86
Blank	(0·14 in 6·91)	——	(0·14 in 5·77)
Correction for nitrite	+ 0·01	——	+ 0·02
"X" nitrogen	0·16	——	0·21
Organic nitrogen, by Kjeldahl, *with* reduction.	0·33	——	0·35
Organic nitrogen, by Kjeldahl, *without* reduction: Taking ammonia by distillation	None.	——	None.
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once.*	0·37	0·54	0·58
" " " *after four hours*	1·80	——	——
Oxygen absorbed from permanganate in sample incubated for five days at 26·7° C. (80° F.); *at once*	0·38	——	0·34
" " " *after four hours*	1·69	——	1·58 (3½ hours).
Smell after incubation	Sweet; earthy.	Sweet.	Sweet.
Chlorine	9·66	——	9·50
Gases: parts per 1,000, *by volume.*			
Oxygen (by cuprous chloride); (a) When sample was drawn	——	——	——
(b) When sample was analysed	About 1·0 (two observers). (Green and dim.)	——	About 0·75 (two observers). (Very green.)
Remarks	When drawn this had a slight smell and was rather cloudy. On 14th December it was lemon-coloured and somewhat dim, with a small but appreciable amount of fine brown flocculent matter. Slight but decided smell, like that of the flower of the castor oil plant (not a bad smell).	This was cloudy and had a sewage smell when drawn. The incubated sample was very yellow but clear, with a little dark grey sediment. Practically no smell; if anything, fishy.	Clear, and of a pale lemon tint, with either no sediment or practically none. Clean smell (slightly fishy-earthy).

SOUTH NORWOOD SEWAGE FARM, 1900–1.

(Special Experiment—*continued.*)

194c First Field Effluent.	194d Second Field Effluent. (Rain.)	195a First Field Effluent.	195 Second Field Effluent.
Saturday, 15th December 1900, 10.45 a.m.	Saturday, 15th December 1900, 11.45 a.m.	Monday, 17th December 1900, 12 noon.	Monday, 17th December 1900, 11 a.m.
9·4° C. (49° F.)	8·9° C. (48° F.)	7·8° C. (46° F.)	7·2° C. (45° F.)
10·6° C. (51° F.)	10·6° C. (51° F.)	8·3° C. (47° F.)	8·3° C. (47° F.)
—	—	Jointed and incubated, 18th December, partly on top of incubator.	—
17th December 1900.	17th December 1900.	Opened 3rd January 1901.	18th December 1900.
—	Turbid.	—	Turbid.
—	0·93	—	1·64 (Probably a trifle low.)
—	0·14	—	0·15
None.	0·02	—	0·13
	1·15	—	0·96
—	2·41	—	3·00
—	(0·14 in 3·66)	—	(0·14 in 4·43)
—	+ 0·01	—	+ 0·07
—	0·17	—	0·12
—	0·31	—	0·27
—	None.	—	0·02
0·51	0·27	—	0·59
—	1·56	—	1·95
—	0·36	—	0·44
—	1·23	—	1·92
—	Sour smell.	—	Doubtful (not putrid).
—	7·36	—	8·86
—	—	—	1·5
None, or merest trace.	Less than 1·0 (Three observers.)	—	0·2 to 0·3 (Pale green.)
This had a sewage smell when drawn, and a dirty bluish-green colour. On 17th December it still smelt of sewage and was very turbid.	When drawn this was slightly cloudy, and had very little smell. On 17th December it was lemon-coloured and slightly cloudy, with a moderate amount of brownish flocculent matter. Slight sewage smell.	Putrid when drawn. When opened on 3rd January this smelt strongly of sulphuretted hydrogen, and contained an appreciable amount of very black sediment. Not analysed.	Lemon-coloured and slightly turbid, with a small but appreciable amount of brown-red flocculent matter. Clean, slightly fishy-earthy smell.

SOUTH NORWOOD SEWAGE FARM 1900–1.

(Special Experiment—*continued.*)

No. of Sample	196	197	197a	198
Nature of Sample	First Arable Field Effluent.	Second Field Effluent.	First Arable Field Affluent.	Second Field Effluent.
Drawn	Wednesday, 19th Dec. 1900, 12.45 noon.	Wednesday, 19th December 1900, 2 p.m.	Thursday, 20th December 1900, 12.40 noon.	Thursday, 20th December 1900, 11.40 a.m.
Temperature of sample	8·3° C. (47° F.)	7·2° C. (45° F.)	8·9° C. (48° F.)	8·9° C. (48° F.)
Temperature of air	7·2° C. (45° F.)	6·7° C. (44° F.)	10·0° C. (50° F.)	10·6° C. (51° F.)
If jointed or incubated	Jointed and incubated 20th Dec., partly on top of incubator.	—	Jointed and incubated 21st Dec. (on top one day).	—
Analysed	Opened 3rd Jan., 1901.	20th December 1900.	Opened 21st Dec. 1900.	21st December 1900.
Parts per 100,000 *by weight.*				
Ammoniacal nitrogen (a) by direct Nesslerization.	—	Turbid.	—	Very turbid.
Ammoniacal nitrogen (b) by distillation.	—	1·96	—	0·96
Albuminoid nitrogen	—	0·34	—	0·19
Nitrous nitrogen	—	0·36	—	0·14
Nitric nitrogen	—	0·59	—	1·60
Total nitrogen by Kjeldahl, *with* reduction.	—	3·68	—	(a) 3·11 (b) 3·10
Blank	—	(0·15 in 5·24)	—	(0·14 in 4·58)
Correction for nitrite	—	+ 0·17	—	+ 0·07
"X" nitrogen	—	0·43	—	0·22
Organic nitrogen by Kjeldahl, *with* reduction.	—	0·77	—	0·41
Organic nitrogen by Kjeldahl, *without* reduction:				
(a) Taking ammonia by direct Nesslerization.	—	—	—	—
(b) Taking ammonia by distillation	—	1·43	—	0·11
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once.*	—	1·02	—	0·44
" " " *after four hours*	—	5·38	—	1·99
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once*	—	*3·01 } 11 days	—	0·54 } 11 days.
" " " *after four hours*	—	4·97 }	—	2·52 }
Smell after incubation	—	Blackened; strong smell of sulphide.	—	Sweet.
Chlorine	—	6·84	—	8·34
Gases: parts per 1,000, *by volume.*				
Oxygen (by cuprous chloride):				
(a) When sample was drawn	—	None.	—	0·25
(b) When sample was analysed	—	None.	—	About 0·3
Remarks	When drawn this sample was cloudy and had a strong sewage smell. After incubation it contained much black sediment and smelt strongly of sulphuretted hydrogen. Not analysed.	There had been 0·3 in. of rain on the night of the 18th–19th. When drawn this sample was cloudy, with a sewage smell. On 20th December it was brown, very dim, and with a very appreciable amount of brown flocculent sediment. Smell, earthy, with a trace of sewage in it.	When drawn this was cloudy, with a sewage smell. After incubation it had a large black deposit and strong sulphuretted hydrogen odour. Not analysed.	Slight smell when drawn. Lemon-coloured, but only slightly dim, and with hardly any flocculent matter. Smell quite sweet, but slightly fishy-earthy.

* *Note.*—Nearly all this excess (*i.e.*, 3·01–1·02) was due to sulphuretted hydrogen.

SOUTH NORWOOD SEWAGE FARM, 1900–1.

(Special Experiment—*continued.*)

198 Large Duplicate.	199 First Field Effluent.	200 Second Field Effluent.	200 Small Duplicate.
—	Wednesday, 2nd January 1901, 2.30 p.m.	Wednesday, 2nd Jan. 1901, 2.30 p.m.	—
—	6·1° C. (43° F.)	5·0° C. (41° F.)	
—	3·3° C. (38° F.)	3·9 C. (39° F.)	
Jointed, 21st Dec. 1900.	—	—	Jointed and incubated 3rd Jan.
13th February 1901.	3rd January 1901.	3rd January 1901.	Opened 8th Jan. 1901.
—	4·78 (on 5 c.c.)	4·28 approx. (on 10 c.c.)	—
0·96	3·13 (on 10 c.c.)	2·78	—
0·11	0·49	0·42	—
0·06	0·14	0·12	—
0·64 (?)	0·23	0·41	—
2·79	Without sugar. 4·53 (0·11 in 6·58) / With sugar. (a) 4·90 (0·14 in 7·15) (b) 4·42 (0·14 in 6·45)	4·22	—
(0·20 in 4·24)		(0·14 in 6·24)	—
+ 0·03	+ 0·07	+ 0·06	—
?	0·54 / 0·91 / 0·43	0·49	—
?	1·03 / 1·40 / 0·92	0·91	—
—	None (−0·79)	—	—
None.	0·86	0·41	—
0·49	1·46	1·18	—
1·92	7·39	5·13	—
0·44 1·90	4·20 † 7·22 †	2·76 5·19	— —
Strong earthy.	Black; strong sulphide.	Strongly putrid.	—
—	8·76	9·20	—
— —	None. None.	None. None.	— —
Clear, but distinctly brown in colour, with a little fine brown sediment. Slight fishy smell.	Strong sewage smell when drawn. On 3rd January very turbid, with much grey flocculent matter. Fishy or soapy smell. † Duplicate titrations with a bottle half full of liquid gave the figures— 0·99 3·84 The liquid smelt of sulphuretted hydrogen, but was not blackened.	Strong sewage smell when drawn on 3rd January; turbid, but less so than No. 199, and with much grey flocculent matter. Fishy or soapy smell.	Liquid very strongly putrid, and sediment black. Not analysed.

SOUTH NORWOOD SEWAGE FARM, 1900.

Street Washings.

No. of Sample	174.	179.	182.	187a.
Nature of Sample	Street Water (small sample).	Surface Water from streets (small sample).	Street Washings. After running two hours.	Street Water. After 0·04″ rainfall.
Drawn	Wednesday, 14th November 1900, 2.15 p.m.	Wednesday, 21st November 1900, 1 p.m.	Wednesday, 28th November 1900, 12·45 noon.	Saturday, 1st December 1900, 11.15 a.m.
Temperature of sample	10·6° C. (51° F.)	8·3° C. (47° F.)	9·4° C. (49° F.)	7·8° C. (46° F.)
Temperature of air	10·6° C. (51° F.)	8·3° C. (47° F.)	8·9° C. (48° F.)	8·3° C. (47° F.)
If jointed or incubated	Incubated 15th November (partly on top of incubator).	Jointed and incubated (partly on top of incubator) 23rd November.	——	Jointed and incubated (partly on top of incubator) 2nd December.
Analysed	4th December 1900.	1st December 1900.	29th Nov. 1900.	17th Dec. 1900.
Parts per 100,000, *by weight.*				
Ammoniacal nitrogen, by distillation	0·19	1·25	0·47	0·52
Albuminoid nitrogen	0·06	0·14	0·42	0·08
Nitrous nitrogen	0·24	——	Trace.	0·10
Nitric nitrogen			0·42	
Total nitrogen by Kjeldahl, *with* reduction (after correction for nitrite).	——	——	1·96	——
Blank	——	——	(0·14 in 3·01)	——
Correction for nitrite	——	——	None.	——
"X" nitrogen	——	——	0·65	——
Organic nitrogen by Kjeldahl, *with* reduction.	——	——	1·07	——
Organic nitrogen by Kjeldahl, *without* reduction:				
Taking ammonia by distillation	——	0·30	(a)[1] 0·66 (b)[1] 0·80	——
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once.*	0·39	——	2·76	0·23
" " " *after four hours*	——	——	9·79	——
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once*	——	——	2·98 six days.	——
" " " *after four hours*	——	——	9·98	——
Smell after incubation	No smell.	Putrid.	Strongly putrid.	Clean smell.
Chlorine	——	——	4·14	——
Gases: parts per 1,000, *by volume.*				
Oxygen (by cuprous chloride): When sample was drawn	1·25	Under 1·0	——	——
Remarks	This liquid had a slight brown tinge and there was much dark-brown sediment, evidently sand. Mr. Kershaw wrote afterwards:— "Numbers 174 and 179 "will be fair samples "of street washings, as "no other water but "(periodically) that "from the South Nor-"wood baths enters "the culvert." This water ultimately joined the sewage from the settling tanks. This sample was very pure for a street water, chemically speaking.	When received, this sample had no smell, but after incubation it showed a small black deposit and had a strong smell of sulphuretted hydrogen	Very turbid grey-brown liquid when stirred up. The filtered liquid was brown, but fairly clear. Much grit. No smell. Alkaline. (a)[1] The clear liquid; (b)[1] The residual turbid liquid distilled. This result again shows absorption.	A good deal of dark-coloured flocculent sediment in bottle. Sweet. This is remarkably pure for a street water, chemically

SOUTH NORWOOD SEWAGE FARM, 1900.

Brook Water alone and admixed with Effluent.

SOUTH NORWOOD SEWAGE FARM, 1900.

Brook Water alone and admixed with Effluent.

No. of Sample	31.	32.
Nature of Sample	General Effluent.	Chaffinch Beck Water, 20 yards *above* junction with effluent.
Drawn	Tuesday, 30th January 1900, 4 p.m.	Tuesday, 30th January 1900, 4.45 p.m.
Temperature of sample	3·3° C. (38° F.)	3·9° C. (39° F.)
Temperature of air	—	—
If jointed or incubated	—	—
Analysed	31st January 1900.	1st February 1900.
Parts per 100,000, *by weight.*		
Ammoniacal nitrogen (a) by direct Nesslerization.	—	Turbid
Ammoniacal nitrogen (b) by distillation	—	—
Albuminoid nitrogen	—	—
Nitrous nitrogen	0·02	none
Nitric nitrogen	—	—
Total nitrogen by Kjeldahl, *with* reduction (after correction for nitrite).	2·47	0·75
Blank	(0·44 in 4·39)	(0·44 in 1·64)
Correction for nitrite	+0·01	none
"X" nitrogen	—	—
Organic nitrogen, by Kjeldahl, *with* reduction	—	—
Oxygen absorbed from permanganate *at* 26·7° C. (80° F.) *at once.*	0·29	0·09
,, ,, ,, *after four hours*	1·30	0·68
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.) *at once*	0·50	0·12
,, ,, ,, *after four hours*	1·57	0·64
Smell after incubation	Doubtful	No smell
Chlorine	7·54	3·20
Gases: parts per 1,000, *by volume.*		
Carbon dioxide (free)	27·21	7·72
Oxygen (boiled out)	5·42	8·35
Oxygen, by cuprous chloride:		
(a) When sample was drawn	—	—
(b) ,, ,, analysed	—	—
Nitrogen	17·91	17·22
Remarks	This contained an appreciable amount of brownish flocculent matter in rather small particles. Earthy smell. Slowly alkaline. A great deal of lime and a good deal of sulphate in solution.	Turbid, from a considerable amount of brownish flocculent matter. No appreciable odour. Just alkaline. A good deal of lime and a moderate amount of sulphate in solution.

SOUTH NORWOOD SEWAGE FARM, 1900.

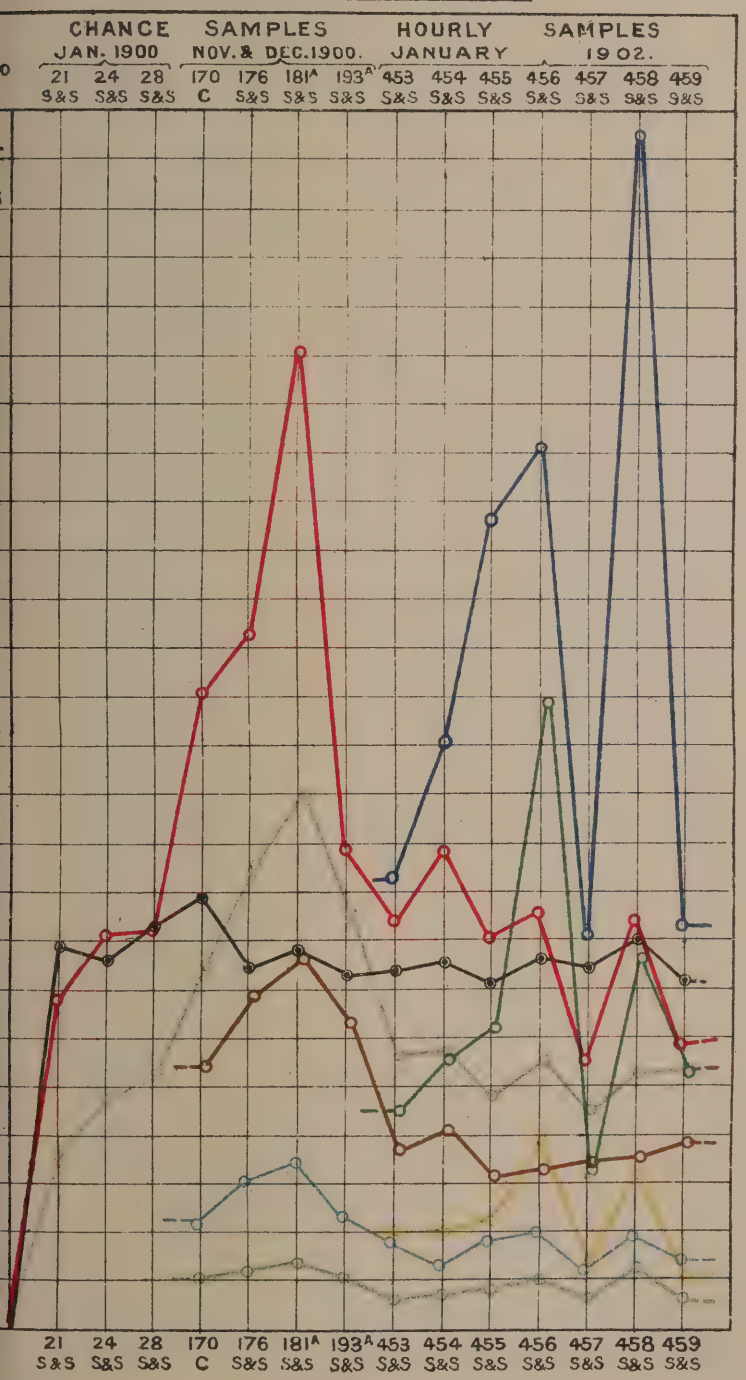
Brook Water alone and admixed with Effluent.

33.	34.	180b.
CHAFFINCH BECK WATER, containing effluent; 20 yards *below* effluent outfall.	CHAFFINCH BECK WATER, containing effluent; 446 yards *below* Sample No 33.	CHAFFINCH BECK WATER, containing effluent; 55 yards *below* effluent outfall.
Tuesday, 30th January 1900. 5 p.m.	Tuesday, 30th January 1900, 5.30 p.m.	Friday, 23rd November 1900, 1 p.m.
3·9° C. (39° F.)	3·9° C. (39° F.)	7·2° C. (45° F.)
—	—	7·2° C. (45° F.)
—	—	—
1st February 1900.	2nd February 1900.	24th November 1900.
Turbid	Turbid	—
—	—	1·41
—	—	0·09
0·01	0·01	trace
—	—	0·25
1·72	1·67	2·07
(0·59 in 3·34)	(0·59 in 3·26)	(0·12 in 3·07)
+0·01	+0·01	none
—	—	0·32
—	—	0·41
0·20	0·25	0·30
1·08	1·23	Not done
0·22 1·10	0·17 0·94	0·55 1·23
No smell	Earthy	Sweet
5·84* *This figure indicates a mixture of about equal volumes of effluent and of stream water.	5·50	7·20
17·14	14·33	—
6·54 This liquid had to be transferred to measuring flask; boiled out after No. 32.	7·20	—
—	—	3·5 when drawn About 2·5 2·75 } Three observers Just below 3·0
—	—	
17·30	17·36	New standard tubes. Liquid very difficult to compare.
Very appreciable amount of flocculent matter, including one or two rather large pieces (one black) which were rejected. No appreciable odour in the cold. Just alkaline. Much lime and much sulphate in solution.	Appreciable amount of brownish flocculent matter. No appreciable odour. Slowly alkaline. A great deal of lime and a moderate amount of sulphate in solution.	Small but appreciable amount of brownish flocculent matter. The liquid had a light brown tint. Clean smell. Mr. Kershaw wrote on 23rd November:— "There was sewage weed in the stream for many yards down. The volume of effluent to that of stream water was 3 : 1."

Diagram No. 28.

SOUTH NORWOOD SEWAGE FARM.

SEWAGES. CURVES.



Nature of Sewage

C = *Crude*

S&S = *Screened & Settled*

REFERENCE

Parts per 100,000, by Weight.

Albuminoid Nitrogen ..... *Shewn thus*

Organic Nitrogen by Kjeldahl, with Reduction .....

Ammoniacal Nitrogen .....

Total Nitrogen by Kjeldahl, with Reduction .....

"Oxygen absorbed" from Permanganate at 26·7°C (80°F.) in four hours .....

Chlorine (Combined) .....

Solids in Suspension (Gravimetrically) (Scale divided by 10) .....

Cellulose (still containing fat) .....

Parts per 100,000, by Volume

Solids in Suspension (by Centrifuge) (Scale divided by 10)

Note

Figures in the Vertical line represent "Parts per 100,000."

Figures in the Horizontal line represent the numbers of the Samples analysed.

A dotted line is used when there is a break in the curve.

2.10.02.

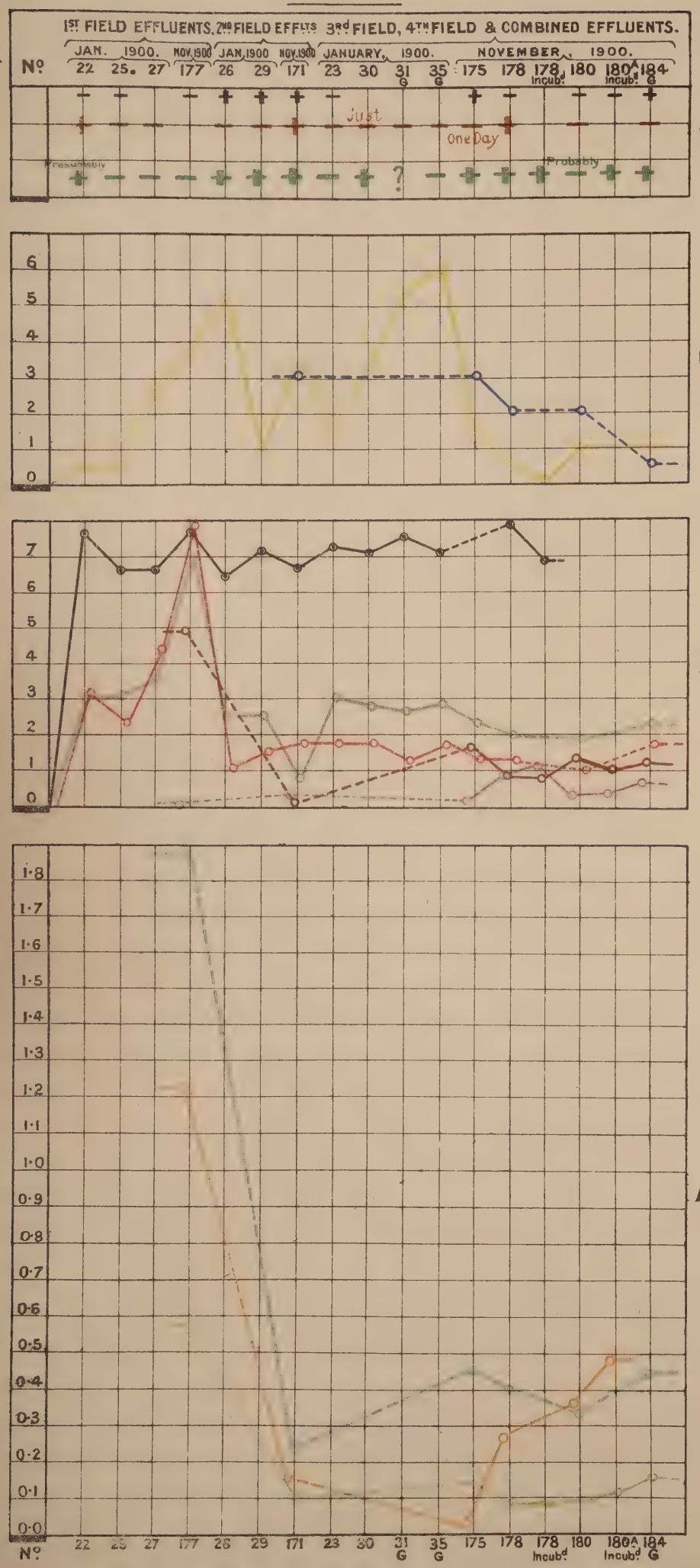
Weller & Graham Ltd Litho. London.

Diagram No 29.

SOUTH NORWOOD SEWAGE FARM.

1ST FIELD, 2ND FIELD, 3RD & 4TH FIELD & COMBINED EFFLUENTS.

CURVES.



REFERENCE

Smell of Samples when drawn Shewn thus + or −

Scudder's Incubation Test + −

Incubation test as judged by Smell + −

Parts per 1,000, by Volume (C.C. per Litre)

Dissolved Oxygen when sample was drawn Shewn thus

Dissolved Oxygen when sample was analysed

Parts per 100,000, by Weight.

Ammoniacal Nitrogen Shewn thus

Total Nitrogen by Kjeldahl, with Reduction

Nitric + Nitrous Nitrogen (together)

"Oxygen absorbed" from Permanganate at 26·7°C (80°F.) in four hours

Chlorine (Combined)

Parts per 100,000, by Weight.

Albuminoid Nitrogen Shewn thus

Organic Nitrogen by Kjeldahl, with Reduction

Organic Nitrogen by Kjeldahl, without Reduction

Note

Figures in the Vertical line represent "Parts per 100,000."

Figures in the Horizontal line represent the numbers of the Samples analysed.

A dotted line is used when there is a break in the curve.

"Incubated" Indicates a sample jointed and allowed to stand for five days or longer at a temperature of 26.7°C (80°F.).

G = *General Effluent.*

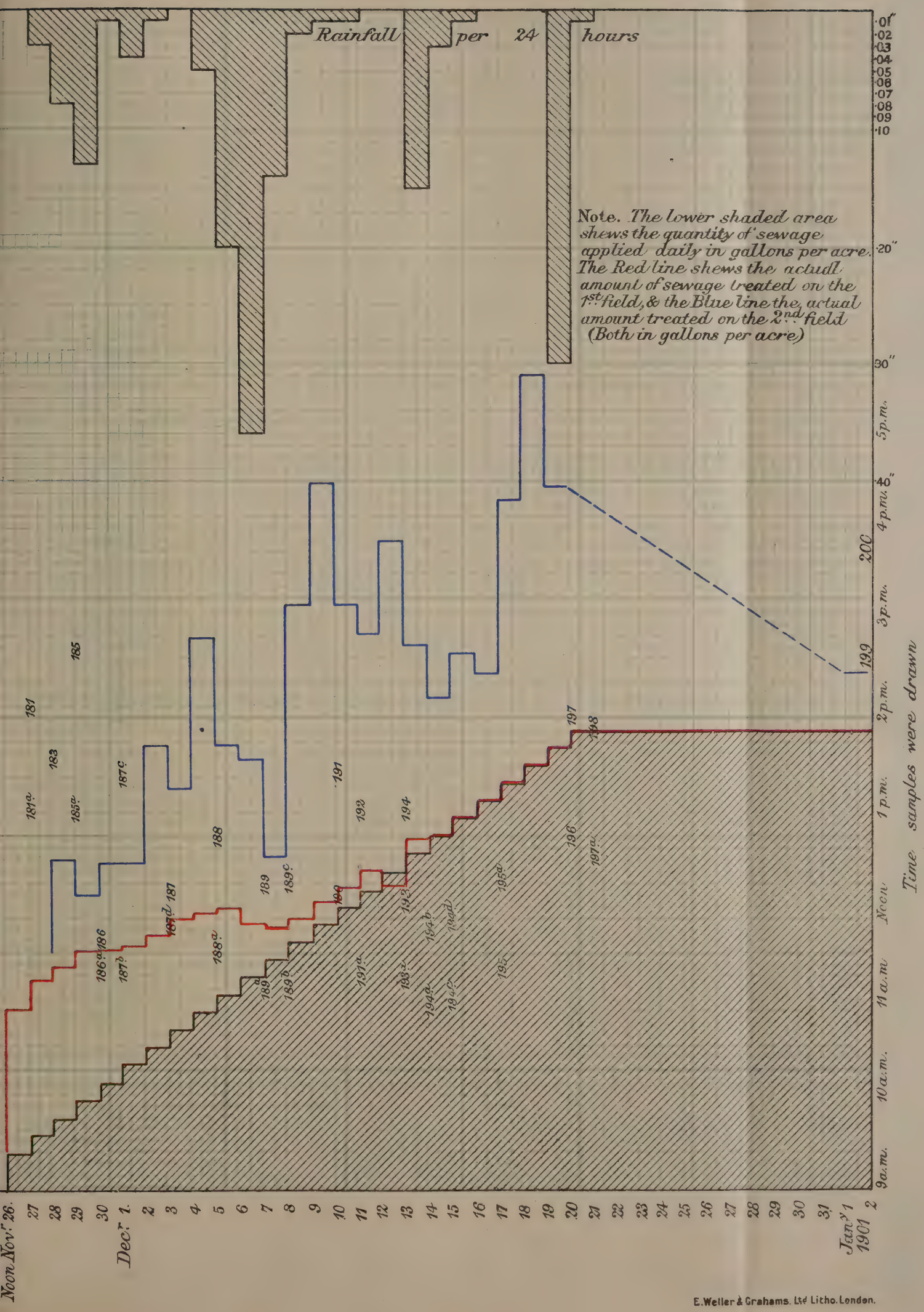
3332. 9. 02.

Weller & Graham, Ltd Litho. London.

Diagram No. 30.
(Engineering Report Diagram)

SOUTH NORWOOD SEWAGE FARM.

(Experiment)

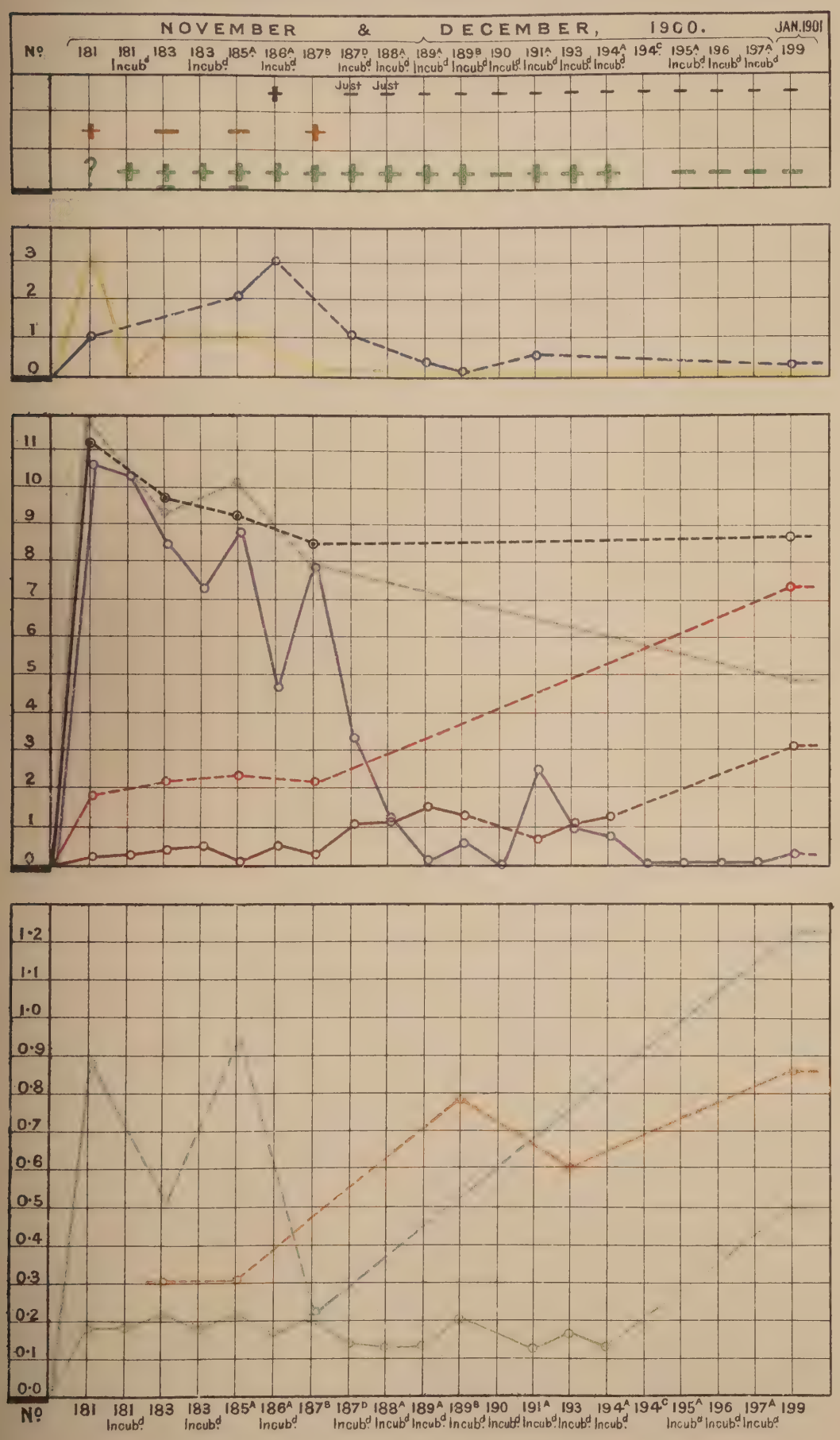


E. Weller & Grahams. Ltd Litho. London.

Diagram No. 31.

SOUTH NORWOOD SEWAGE FARM.

SPECIAL EXPERIMENT. 1ST FIELD EFFLUENTS. CURVES.



REFERENCE

Smell of Samples when drawn *Shewn thus* + or −

D *Scudder's Incubation Test* + −

Incubation test as judged by Smell + −

Parts per 1.000, by Volume (C.C. per Litre)

C *Dissolved Oxygen when sample was drawn* *Shewn thus* ——

Dissolved Oxygen when sample was analysed ——

Parts per 100.000, by Weight

Ammoniacal Nitrogen ..... *Shewn thus* ——

Total Nitrogen by Kjeldahl, with Reduction ..... ——

B *Nitric + Nitrous Nitrogen (together)* ..... ——

"Oxygen absorbed" from Permanganate at 26·7°C (80°F.) in four hours ..... ——

Chlorine (Combined) ..... ——

Parts per 100.000, by Weight.

Albuminoid Nitrogen ..... *Shewn thus* ——

Organic Nitrogen by Kjeldahl, with Reduction ..... ——

A *Organic Nitrogen by Kjeldahl, without Reduction* ..... ——

Note

Figures in the Vertical line represent "Parts per 100.000."

Figures in the Horizontal line represent the numbers of the Samples analysed.

A dotted line is used when there is a break in the curve.

"Incubated" Indicates a sample jointed and allowed to stand for five days or longer at a temperature of 26.7°C (80°F.)

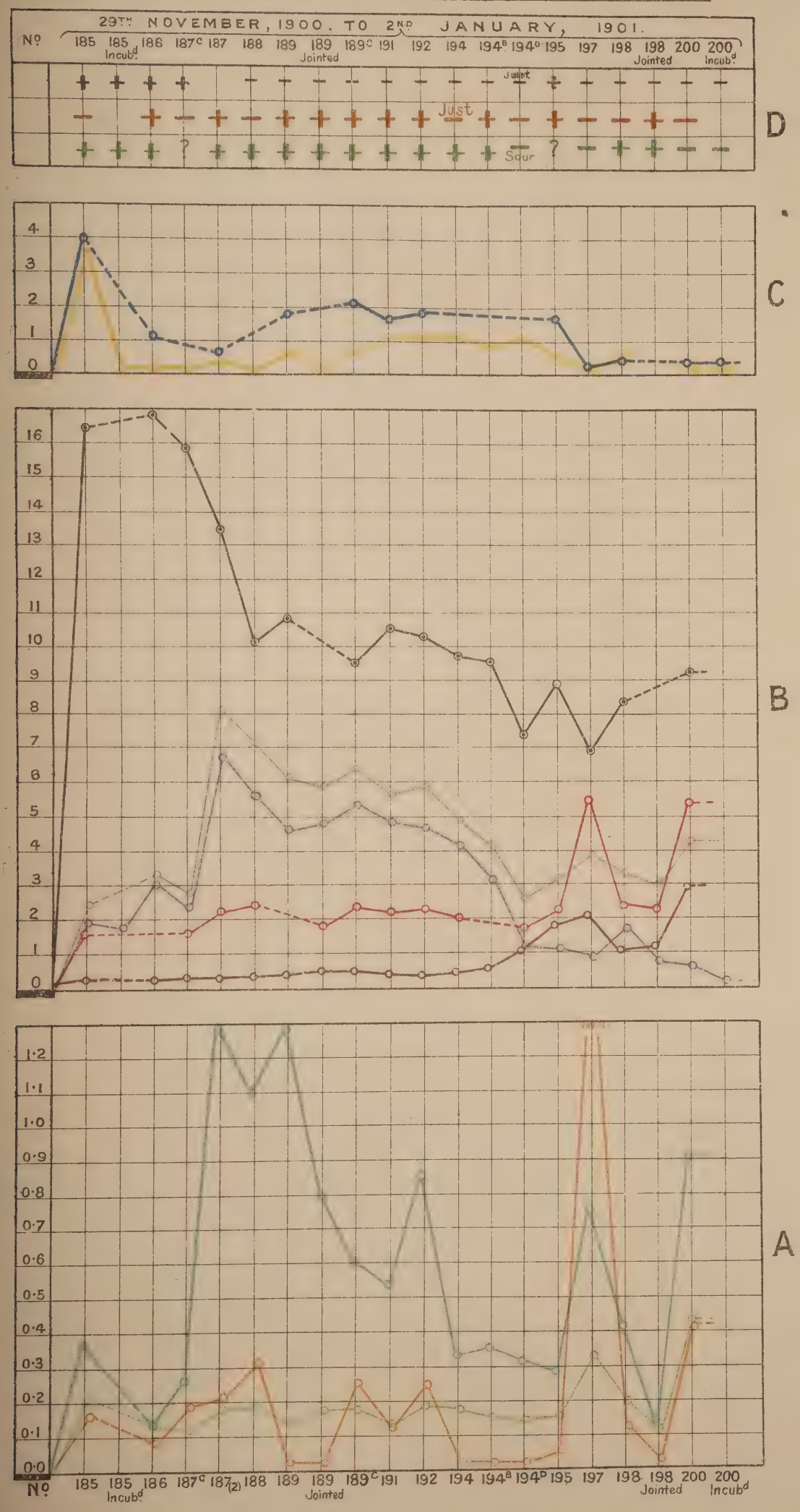
3332. 9. 02.

Weller & Graham Ltd Litho. London

SOUTH NORWOOD SEWAGE FARM.

SPECIAL EXPERIMENT. 2ND FIELD EFFLUENTS. CURVES.

Diagram No. 32.



REFERENCE

Smell of Samples when drawn Shewn thus + or −

Scudder's Incubation Test + −

Incubation test as judged by Smell + −

Parts per 1000, by Volume (C.C. per Litre)

Dissolved Oxygen when sample was drawn Shewn thus

Dissolved Oxygen when sample was analysed

Parts per 100.000, by Weight.

Ammoniacal Nitrogen Shewn thus

Total Nitrogen by Kjeldahl with Reduction

Nitric + Nitrous Nitrogen (together)

"Oxygen absorbed" from Permanganate at 26·7°C (80°F.) in four hours

Chlorine (Combined)

Parts per 100.000, by Weight.

Albuminoid Nitrogen Shewn thus

Organic Nitrogen by Kjeldahl, with Reduction

Organic Nitrogen by Kjeldahl, without Reduction

Note

Figures in the Vertical line represent "Parts per 100.000."

Figures in the Horizontal line represent the numbers of the Samples analysed.

A dotted line is used when there is a break in the curve.

"Jointed" Indicates a sample jointed and allowed to stand at laboratory temperature.

"Incubated" Indicates a sample jointed and allowed to stand for five days or longer at a temperature of 26.7°C (80°F.).

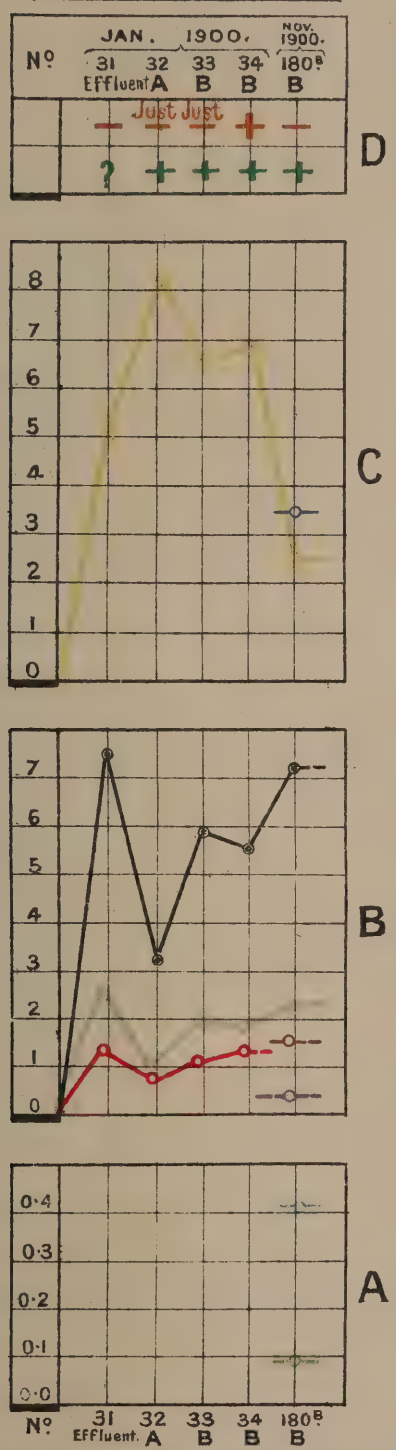
3332. 9. 02.

Weller & Graham Ltd Litho London.

Diagram No. 33.

SOUTH NORWOOD SEWAGE FARM:

BROOK WATER. CURVES.



REFERENCE

Scudder's Incubation Test + −

Incubation test as judged by Smell + −

Parts per 1000, by Volume (C.C. per Litre)

Dissolved Oxygen when sample was drawn Shewn thus

Dissolved Oxygen when sample was analysed

Parts per 100.000, by Weight.

Ammoniacal Nitrogen Shewn thus

Total Nitrogen by Kjeldahl, with Reduction.

Nitric + Nitrous Nitrogen (together)

"Oxygen absorbed" from Permanganate at 26·7°C (80°F.) in four hours.

Chlorine (Combined)

Parts per 100.000, by Weight.

Albuminoid Nitrogen Shewn thus

Organic Nitrogen by Kjeldahl, with Reduction

Note. A *Indicates a sample drawn from Above Effluent Outfall.*
B. " " " " " *Below* " " "

Note

Figures in the Vertical line represent "Parts per 100.000."

Figures in the Horizontal line represent the numbers of the Samples analysed.

A dotted line is used when there is a break in the curve.

3332. 10. 02.

Weller & Graham Ltd Litho. London.

NOTTINGHAM SEWAGE FARM.

Chemical Report.

1. Situation of farm—Stoke Bardolph, about five miles from Nottingham.
2. Total acreage of farm—907 acres (1900).
3. Total irrigable area—651 acres (1900).
4. Average area irrigated at one time—300 acres.
5. Population draining to farm—258,584*
6. Population per acre irrigated—397.
7. Gallons of sewage per head per day—27.
8. Dry weather flow of sewage per 24 hours—7,000,000 gallons.
9. Gallons of sewage treated per acre per 24 hours—23,300.
10. Gallons of sewage treated per acre per 24 hours, on the assumption that each acre of the irrigable area is under sewage all the time—10,750.
11. Character of the sewage—4-7ths domestic, 3-7ths trade refuse.
12. Method of treatment—Screening (partial) and land filtration.
13. General character of the soil and subsoil—Light sandy loam and gravel overlying gravel and sand.
14. Separate or combined sewerage system—Combined.
15. The final effluent is discharged into—River Trent.
16. Number of years farm has been in operation (before 1900)—19½ years.

* It will, however, be seen from the Engineering Report (Part IV.) that a large proportion of the fæcal matter is kept out of the sewers.

NOTTINGHAM SEWAGE FARM.

As has been already stated in the Engineering Report* and reprinted in tabular form at the beginning of this one, the area of land actually irrigated in the course of the year on the Nottingham farm amounts to 651 acres, of which 615 acres are arable and 36 acres are pasture. These 615 acres include the 120 acres which are kept permanently uncropped.

The whole of the farm is under-drained, the main drains being laid at a depth of 6ft. to 10ft., and the feeder drains at a depth of 4ft. 6in. to 7ft. 6in. ; 120 acres of the farm are drained twice as closely as the rest of it. *All the effluents are therefore percolation effluents*, which have passed once through a very considerable depth of soil and subsoil of excellent—one might almost say of ideal—quality for the purpose. There is practically no subsoil water on the farm (*cf.* Engineering Report*).

* Part IV., Engineering and Practical Report.

Soil and Subsoil.

The soil—a light, porous, sandy loam—varies in depth from 7in. to 15in., while the subsoil is composed of river valley gravel. The mechanical composition of these is shown by the following analysis of average samples, drawn by Mr. Kershaw :—

Name of Fraction.	Surface Soil per cent.			Subsoil per cent.		
	Not Ignited.	Ignited.	Difference.	Not Ignited.	Ignited.	Difference.
"Gravel" (above 8·0 m.m. diameter) - -				25·47	25·47	
Fine "Gravel" (above 2·0 m.m. diameter) -	17·20	16·67	0·53	14·99	14·65	0·34
Coarse "Sand" (above 1·0 m.m. diameter) -	1·88	1·59	0·29	2·98	2·93	0·05
Coarse "Sand" (above 0·5 m.m. diameter) -	1·44	1·31	0·13	3·00	2·94	0·06
Medium "Sand" (above 0·25 m.m. diameter)	3·54	3·44	0·10	8·22	8·16	0·06
"Sand" (0·25 to 0·05 m.m.) - - -	45·14	44·24	0·90	40·14	39·88	0·26
"Silt" (0·05 to 0·01 m.m.) - - -	17·00	15·42	1·58	1·89	1·80	0·09
"Dust" (from 0·01 m.m. downwards, which settles from water in 24 hours) - -	11·16	8·89	2·27	1·85	1·63	0·22
"Clay" (*i.e.*, the still finer residue precipitated from the water by dilute nitric acid) - - - - - - - -	1·74	1·44	0·30	0·67	0·60	0·07
Loss on ignition (separate determination) -		6·16			1·28	
	99·10	99·16	6·10	99·21	99·34	1·15
Real specific gravity of soil dried at 110° C.	2·566			2·695		
Apparent specific gravity ,, ,,	1·442			1·773		
Number of particles in 1 gramme of the ignited soil or subsoil (approx.) - -	819,191,490.			290,000,370.		
Number of particles in 1 c.c. of the ignited soil or subsoil (approx.) - - - -	1,181,291,470.			514,162,730.		
Weight of water retained by 100 grammes of the soil, when fully drained - -	34·4			26·6		
Parts per 100,000.						
Lime dissolved by water in 24 hours - -	0·009			0·017		
Lime dissolved by water, saturated with carbonic acid, in 48 hours - - -	0·060			0·070		

For a discussion of the figures given in this table, *see* the Section upon Soils, page 275.

Volume treated per Acre, etc.

The dry weather flow of sewage treated on the farm is 7,000,000 gallons, of which about three-sevenths, or 40 per cent., is trade refuse from bleach, dye, wool-scouring, fellmongers' and bone works, together with breweries and laundries. The dye and bleach refuse preponderate. The population draining to the sewage farm is given by Mr. Kershaw as 258,584; so that, roughly speaking, the sewage (including trade refuse) amounts in *dry weather* to 27 gallons per head. This, however, takes no account of the portion of the storm water which is treated on the farm. The number of persons per acre irrigated is 397 (this is, however, subject to the note on p. 195). As the water supply is only 18 gallons per head, the remaining 9 gallons must be mainly trade refuse, as very little subsoil water gets into the sewers.

As stated already, there is practically no subsoil water on the farm.

The average area under irrigation at Nottingham on one day is 300 acres, an acre treating 23,300 gallons in 24 hours; but in order that a comparison may be made between different farms, it will be convenient to imagine each acre of irrigable area as being under sewage all the time. *On this assumption, each acre of ground at Nottingham treats* 10,750 *gallons per* 24 *hours all the year round.*

Nature of Sewage (*Diagram* No. 34.)

This is rather strong and decidedly alkaline, but owing to its long journey it arrives at the farm in a well broken-up condition.

Four chance samples (Nos. 10, 13, 109 and 114), and three sets of hourly samples, each set extending over a period of 24 hours (Nos. 466, 467, 468), were analysed. These hourly samples were drawn in equal quantities each hour (not according to rate of flow), and are therefore probably below the true average in strength, excepting that No. 466 contained more than its fair share of suspended solids, on account of some rain which fell previous to its being taken, and which apparently washed out the sewers.

The details of the analyses are given in the appended Tables of Analysis and Curves. A summary of these results may, however, be given here.

	Average.
Total Nitrogen—(*a*) 4 chance samples (4·68 to 7·86)	6·39
(*b*) 3 sets of hourly samples (7·53 to 7·82)	7·69
Ammoniacal Nitrogen—(*a*) 4 chance samples (3·21 to 5·32)	3·92
(*b*) 3 sets of hourly samples (3·08 to 4·53)	3·98
Total Organic Nitrogen—(*a*) 4 chance samples (1·47 to 4·24)	2·42*
(*b*) 3 sets of hourly samples (2·56 to 4·21)	3·15
Albuminoid Nitrogen—(*a*) 4 chance samples (1·18 to 2·63)	1·77
(*b*) 3 sets of hourly samples (1·17 to 1·99)	1·45
"*Oxygen Absorbed*" in 4 hours at 26·7° C. (80° F.)—(*a*) 4 chance samples (10·97 to 25·06)	17·64
(*b*) 3 sets of hourly samples (21·03 to 26·29)	23·21
Chlorine (*a*) 4 chance samples (9·66 to 23·42)	16·35
(*b*) 3 sets of hourly samples (11·26 to 15·36)	13·68
Chlorine in water supply	1·06
Ratio of Ammoniacal Nitrogen to Chlorine—3 sets of hourly samples (1 : 3·65, 1 : 3·29, 1 : 3·39)	1 : 3·44
Ratio of Ammoniacal Nitrogen to Chlorine, after deducting the chlorine of the water supply—3 sets of hourly samples (1 : 3·31, 1 : 3·05, 1 : 3·16)	1 : 3·17

* This figure for organic nitrogen is probably too low, and not to be relied upon.

Solids in suspension—3 sets of hourly samples (34·4 to 79·2*) - -		51·9
Cellulose still containing fat—3 sets of hourly samples (14·96 to 24·96*) - (One extraction with dilute alkali and one with dilute acid.)		18·41
Cellulose—3 sets hourly of samples (5·32 to 15·08*) - - - - (Extraction with alkali, acid and ether)		8·88
Ratios of Celluloses containing fat to suspended solids 3 sets of hourly samples	1 : 3·2 1 : 2·7 1 : 2·3	1 : 2·7
Ratios of Celluloses to suspended solids 3 sets of hourly samples	1 : 5·3 1 : 6·7 1 : 6·5	1 : 6·2

Probably, however, those two average ratios would be more correct if taken at 2·5 and 6·6 respectively.

Although the analyses are fewer in number than might have been wished, they leave no doubt as to the comparative strength of the sewage, though the amount of ammonia present is not great; it may be taken approximately as containing some 7 to 8 parts of total nitrogen per 100,000, about 3 parts of organic nitrogen, and something like 40 to 50 parts of suspended solids; while the figure obtained for "oxygen absorbed" in four hours is over 20. The ratio of "oxygen absorbed" to organic nitrogen is high (about 7 : 1), this being no doubt due to some of the constituents of the trade refuse. The suspended solids were rather coarse, and contained a good deal of cellulose and grit.

It will be noticed from the figures of the analyses that the hourly samples still contained appreciable quantities of nitrate when analysed, this coming, no doubt, from the subsoil water which finds access to the sewers.

Before leaving the subject a few further points may be referred to, viz :—

(1) The total nitrogen in the hourly samples is about double the ammoniacal nitrogen.

(2) The curves for total nitrogen, organic nitrogen† and albuminoid nitrogen are approximately of the same kind; while in the hourly samples the albuminoid and organic nitrogen curves follow one another perfectly, the total organic nitrogen being rather more than double the albuminoid.

(3) The curves for albuminoid and organic nitrogen on the one hand, and for "oxygen absorbed" on the other, are roughly of the same type, but do not follow one another at all closely. This is no doubt partly due to the presence of oxidisable trade refuse, and partly to the nature of the suspended solids.

(4) The average ratio between albuminoid nitrogen and "oxygen absorbed" in the four chance samples of sewage is 1 : 10·4, and in the three sets of hourly samples 1 : 16·6; in the chance samples this ratio is very uneven, and in the hourly samples also uneven.

(5) In the hourly samples the cellulose curve follows pretty closely the curve for solids in suspension, and the agreement is very marked in the two last analyses, which probably represent the normal condition of the sewage.

(6) The chlorine curve in the hourly samples bears a marked similarity to that for ammoniacal nitrogen, though the ratio between those two constituents is high.

It would, however, be idle to attempt to draw many deductions from so few analyses. Still, those which have just been given are sufficient to indicate the general character of the sewage.

---

* Those figures are, in all probability, higher than the normal, because of the rain which fell before ple No. 466 was drawn; this, doubtless, washed out the sewers to some extent.

† In the chance samples the determinations of organic nitrogen were more or less unsatisfactory.

Effluents. (*Diagram No.* 35.)

As already stated, these are all *percolation* effluents.

Seventeen effluents altogether were examined, 6 of these in duplicate after jointing or incubation, making a total of 23 analyses, full or partial. Some of these effluents were drawn in December, some in July and August, and some in September.

The first thing that strikes one here is the temperature curve (*cf.* Part IV., Engineering and Practical Report). Leaving out of account No. 341, the temperature of which was 18·9 deg. C. (66 deg. F.)*, that of the 16 Nottingham effluents, when drawn, varied only between the narrow limits of 8·9 deg. C. (48 deg. F.), and 13·3 deg. C. (56 deg. F.), winter and summer. The temperatures of the four chance samples of sewage were 15 deg. C. (59 deg. F.), 15 deg. C. (59 deg. F.), 20 deg. C. (68 deg. F.), and 16.6 deg. C. (62 deg. F.), the two first being drawn in December and the two last in July. This point alone, *i.e.*, the comparatively even temperature of the effluents, shows what a great advantage as regards uniformity of working a percolation farm has over one which treats the sewage by surface irrigation.

Leaving out of account the first effluent examined (No. 11), when the ground had been *purposely* over-sewaged, all the effluents were of wonderful quality, the best of them approaching in fact to drinking waters. They were uniformly clear, colourless, and without smell, both when drawn and when analysed, and, until September, 1901, with no sediment, excepting a minute trace of very fine soil which could be detected at the bottom of the sample bottles after the liquid had stood in them for some time. The last samples examined (Nos. 332, 333, 340 and 341), while also clear, colourless, and without smell, contained quite appreciable amounts of red-brown flocculent sediment—no doubt vegetable growth from the drain pipes, coated with hydroxide of iron.

The effluents were all alkaline in reaction, and contained (relatively) a great dea of lime† and much sulphate in solution.

The first two series of effluents (drawn in December, 1899, and in July and August, 1900) were very well aerated for percolation effluents (probably aerated in the drains), containing as they did, when analysed, an average of about 5 c.c. *dissolved oxygen* per litre for 13 samples; and of the two duplicates which were jointed, the oxygen in No. 111 was reduced from 3·0 to 1·6 c.c. per litre in ten days at atmospheric summer temperature, while that in No 121 underwent no reduction in nine days under like conditions, remaining at about 6 c.c. per litre. This is, of course, very remarkable for an effluent, and places it, in this respect, among drinking waters. The last four samples, drawn in September, 1901, were (like No. 111) not so highly aerated as the others when they reached the laboratory, containing an average of about 2·5 c.c.‡ dissolved oxygen; but in every case the duplicates retained something like 1 c.c. of this after being jointed and incubated at 26·7 deg. C. (80 deg. F.) for a fortnight.§

As was to be expected in a percolation effluent, the *free carbon dioxide* was high, an average of five analyses giving 59 c.c. per litre. In two samples (Nos. 18 and 19) the total carbon dioxide—free and combined together—was determined, the figures obtained being 164·9 and 197·4 c c. per litre. As there was little or no saline ammonia present, these figures corroborate the presence of much lime (or lime and magnesia) in the effluent.

Thirteen samples yielded 0·01 to 0·10 albuminoid nitrogen, the average being 0·03 part per 100,000, while the figures for "oxygen absorbed" (from strong permanganate at 80° F.) in four hours were 0·05 to 0·37; average, 0·19.

The effluents (excepting No. 11), of course all remained sweet on *incubation*, as udged by smell. Oddly enough, they were nearly all condemned by Mr. Scudder's

* This high figure was probably owing to the drains being somewhat shallow in the field from which the sample was drawn.

he soil and subsoil were not specially calcareous (see analysis of these).

Those last oxygen readings were a little too high.

For an anomalous result here, see Tables of Analysis, sample No. 340.

incubator test, as judged by difference of oxygen absorbed from permanganate before and after incubation. But this was no doubt owing to the circumstance that the *actual* quantities of permanganate required were so small as to be within the limits of error of experiment, unless special precautions had been taken.

The *total nitrogen* in these effluents (13 analyses) varied between 1·41 and 3·45 parts per 100,000, the average being 2·27 parts. It requires but a glance at the curves to see that this was present almost entirely as nitrate, the average nitric nitrogen, including traces of nitrous, being 2·06 for the same 13 samples. There was practically no nitrite—a further indication of nearly perfect oxidation.

The *ammoniacal nitrogen* was in most cases little more than a trace, generally expressible in the second decimal place, with a minimum of 0·01 and a maximum of 0·29 in 13 analyses, the average being only 0·13.

The *albuminoid nitrogen* in the same number of samples varied between 0·01 and 0·10, and averaged only 0·03 parts per 100,000.

The total *organic nitrogen* in those effluents could not be satisfactorily determined by the usual Kjeldahl process (*i.e.*, Kjeldahl *with reduction*), the error of experiment of the method being too great for such small quantities. The Kjeldahl process *without reduction* was in the case of the Nottingham effluents much more satisfactory, though not in every case reliable; it gave the quantity of total organic nitrogen as something like two to three times that of the albuminoid.

The *nitric* (including traces of nitrous) *nitrogen* has been already referred to, above. Two further points, however, may be noticed here, *viz.*, (*a*) the three highest figures for nitric nitrogen were found in July; (*b*) the last set of samples (Nos. 332, 333, 340 and 341, drawn in September) were rather poorer in nitrate than the others, the average nitric plus nitrous nitrogen in them being 1·44.

The *ratio of oxidised to unoxidised nitrogen* (taking the unoxidised = 1) was, of course, exceedingly high—far higher than in any other set of samples examined; but in view of what has been said above with reference to the determination of organic nitrogen in these effluents, only six will be cited, three of which were "Kjeldahled" after reduction and three without reduction, *viz.*, Nos. 12, 14, 15, 16, 18, and 110. The ratio in those six cases varied between 15 and 51, the average ratio being 35 : 1. No "safety limit" ratio can be suggested here, the sample being so far above any ordinary standard.

The *ratio of oxidised to albuminoid nitrogen* (taking the albuminoid = 1) in the 13 effluents tested varied between 20·6 : 1 and 168·0 : 1 the average being 80 : 1, which is probably a record figure. In every case out of the thirteen, excepting two, the ratio was from 59 : 1 upwards. Here again no "safety limit" ratio can be suggested, for the reason already given.

Only in three samples, each in duplicate, was the nitric (including nitrous) nitrogen determined before and after incubation, either at the summer temperature of the air or in the incubator at 26·7 deg. C. (80 deg. F.); and in none of these cases was the ammoniacal, albuminoid or organic nitrogen determined a second time. No conclusions, therefore, can be drawn here with regard to the quantity of nitric nitrogen used up by the oxidation of the very small amount of organic matter present in these effluents. There was, however, a considerable reduction of nitrate in the incubated duplicate of No. 340 (one of the last set), as compared with the original sample.

It will be seen that the *chlorine* in the effluents examined in December, July, and August (those drawn in September were not tested for chlorine) remained remarkably constant. If we except No. 121, in which the chlorine sank to 9·2 parts per 100,000, owing to a heavy rainfall, the figures for the other twelve samples of effluent only varied between 11·20 and 12·56.

In conclusion.—The Nottingham farm treats on an excellent loamy soil and gravelly sub-soil, most of the land being cropped, a medium volume of a rather strong sewage containing 40 per cent. of trade refuse, the aggregate organic matter treated per acre—apart from volume of liquid—being about two-thirds that at Cambridge (compare Diagrams Nos. 3 and 4). The result is an effluent of altogether exceptional quality, clear and sparkling, and approaching in the best samples within measurable distance—from a chemical point of view—of a drinking water.

The relative numbers of particles per unit weight of ignited soil and sub-soil, and per unit volume of soil and sub-soil, are taken at 100 in both cases, for purposes of comparison with the other farms. The soil and subsoil are of the same type as those at Cambridge, but rather finer. The relative calculated *internal* filtering area down to the drains at Nottingham is about one-third greater than that at Cambridge, and the rate of filtration must be rather slow. (Compare Section on Soils, page 275; also *Conclusions*, page 303.)

There is only one other point to which attention may be drawn before closing, viz.: the rapidity with which the soil of the Nottingham farm recovers itself after being over-sewaged. As already mentioned in Mr. Kershaw's Notes,* Sample No. 11 represents the effluent from a field (fallow) which had been *purposely* sewaged night and day, in order that we might obtain a bad effluent. After this sample had been drawn the plot was sewaged for twelve hours by night only, over a period of seven days, when effluent Sample No. 14 was taken; as will be seen by a reference to the figures, the analysis of this showed the usual high standard.

I trust that in this report the great purity of the Nottingham farm effluents—from a chemical point of view—has not been dwelt upon too much; but one feels that too great stress can hardly be laid upon this, because it shows what admirable results can be obtained from good land under good management.

Percentage purification, as calculated on the albuminoid nitrogen and "oxygen absorbed" in four hours.

(1) *Albuminoid Nitrogen.*

	Average.
(*a*) 4 chance samples of sewage yielded (1·18 to 2·63) - - -	1·77
(*b*) 3 sets of hourly samples yielded (1·17 to 1·99) - - -	1·45
13 samples of effluent yielded (0·01 to 0·101) - - - -	0·03

The percentage purification therefore was :—

(*a*) On the chance samples of sewage - - - -	98·9 per cent.
(*b*) ,, hourly ,, ,, - - - -	97·9 ,,

(2) *Oxygen absorbed.*

(*a*) 4 chance samples of sewage gave (10·97 to 25·06) - - -	1 ·64
(*b*) 3 sets of hourly samples gave (21·03 to 26·29) - - -	23·21
13 samples of effluent gave (0·05 to 0·37) - - - -	0·19

The percentage purification therefore was :—

(*a*) On the chance samples of sewage - - - -	98·9 per cent.
(*b*) ,, hourly ,, ,, - - - -	99·2 ,,

Comparison of the Total Nitrogen in the Sewages and the Effluents.

	Per cent.
The average total nitrogen in 4 chance samples of sewage was -	6·39
,, ,, in 3 sets of hourly samples - - -	7·69
,, ,, in 13 effluents (1·4 to 3·5) - - -	2·3

Mr. Kershaw says in his Report* that there is practically no subsoil water on the farm; so, leaving this out of account, the nitrogen which drains into the river (almost entirely as nitrate) works out from the above figures to something like 30 per cent. of the total nitrogen of the sewage. Since, however, there must have been very great evaporation from the crops when many of the above samples of effluent were being drawn, this is clearly an over-estimate of the loss by drainage.

---

* Part IV.:—Engineering and Practical Report.

Trent River water, with and without admixed effluent. (*Diagram No.* 36.)

Five samples in all were examined, two of them in duplicate, these being drawn in the months of July and August, 1900. Three of them (Nos. 112, 117 and 120) were taken above the effluent outfall, and two (Nos. 122 and 123) below it. They were slightly opalescent, with a considerable quantity of brown deposit, and were, chemically, of very even composition.

For a non-drinking water stream there was nothing offensive about the water, but it was not of high quality, not nearly so good, in fact, as the Nottingham sewage farm effluents. The amount of oxidisable matter present, as measured by the "oxygen-absorbed" test, was very high. Still, the jointed samples, kept for a week to a fortnight in warm summer weather, retained a little dissolved oxygen (No. 117 as much as 4 c.c.) and also a sufficient reserve of nitrate, and kept sweet.

As will be seen from the Table of Analysis and the Curves, the two incubation tests agreed with one another here in the three samples tested.

Of the two Kjeldahl methods for organic nitrogen, that *without* reduction answered better than the other (three samples).

NOTTINGHAM SEWAGE FARM.

TABLES OF ANALYSIS.

INDEX.

PAGE.

Hourly Sewage Samples, Nos. 466, 467, 468 - - - - - - - - - - - - 205

Sewages and Effluents, Nos. 10, 11, 12, 13 - - - - - - - - - - - - 206

Effluents, Nos. 14, 15, 16, 18, 19 - - - - - - - - - - - - - - 207

Sewage and Effluents, Nos. 109, 110, 111 - - - - - - - - - - - - 208

" " Nos. 113, 114, 115, 116, 118, 119 - - - - - - - - - 209

Effluents, Nos. 121, 332 - - - - - - - - - - - - - - - - - 210

" Nos. 333, 340, 341 - - - - - - - - - - - - - - - - 211

River Water above and below Effluent outfall (including one effluent):—Nos. 112, 117, 120, 121, 122, 123 - - - - - - - - - - - - - - - - - 212-213

NOTTINGHAM SEWAGE FARM, 1902.

Hourly Sewage Samples, drawn in equal quantities per hour.

No. of Sample	466	467	468
Nature of Sample	Screened and Crude Sewage. 24 Hours' Sample.	Screened and Crude Sewage. 24 Hours' Sample.	Screened and Crude Sewage. 24 Hours' Sample.
Rainfall while samples were being drawn	*0·0″	0·0″	0·0″
Drawn	From Monday, 3rd February 1902, 12 noon, to Tuesday, 4th February, 11 a.m.	From Tuesday, 4th February 1902, 12 noon, to Wednesday, 5th February, 11 a.m.	From Wednesday, 5th February 1902, 12 noon, to Thursday, 6th February, 11 a.m.
Analysed	5th February 1902	6th February 1902	7th February 1902.
Parts per 100,000, *by weight.*			
Ammoniacal nitrogen (by distillation)	3·08	4·32	4·53
Albuminoid nitrogen	1·99	1·17	1·20
Nitrous nitrogen	0·08	0·05	0·01
Nitric nitrogen	0·45	0·60	0·52
Total nitrogen, by Kjeldahl, *with* reduction.	7·82	7·53	7·73
Blank	(0·45 in 6·16)	(0·45 in 5·95)	(0·45 in 6·10)
"X" nitrogen	2·22	1·39	1·47
Organic nitrogen, by Kjeldahl, *with* reduction.	4.21	2·56	2·67
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once.*	6·02	4·55	5·62
,, ,, ,, *after four hours.*	26·29	21·03	22·32
Chlorine	11·26	14·22	15·36
Total solids (gravimetrically)	169·6 {82·0 volatile. 87·6 non-volatile.}	150·0 {73·8 volatile. 76·2 non-volatile.}	150·4 {73·0 volatile. 77·4 non-volatile.}
Solids in suspension ,,	79·2 {48·8 volatile. 30·4 non-volatile.}	42·0 {23·6 volatile. 18·4 non-volatile.}	34·4 {23·0 volatile. 11·4 non-volatile.}
Solids in solution ,,	90·4 {33·2 volatile. 57·2 non-volatile.}	108·0 {50·2 volatile. 57·8 non-volatile.}	116·0 {50·0 volatile. 66·0 non-volatile.}
Cellulose, still containing fat (by extraction with alkali and acid alone.) (a)	24·96	15·32	14·96
Cellulose (by alkali, acid and ether) (b)	15·08	6·24	5·32
Grit from (a)	11·60	4·88	3·80
,, ,, (b)	11·28	4·36	3·76
Parts per 100,000, *by volume.*			
Solids by centrifuge	Too coarse to centrifuge	Too coarse	Too coarse.
Remarks	Very turbid, with considerable dark-brown deposit and some fairly large pieces of white and brown suspended matter. Slight urine smell. Alkaline. * 0·143 In. of rain fell *before* No. 466 was drawn.	Turbid, with probably a trifle less (apparent) deposit than last sample. It contained some pieces of brown spongy matter which could not be broken up. Slight urine smell. Alkaline.	Turbid, with apparently rather more solids than No. 467, these solids being also more disintegrated. Slight urine smell. Alkaline. February 15th.—General solids up to 2·3 m.m. long; wood fibre up to 1·9 m.m.; hair up to 1·14 m.m. At this date, February 15th, there were swarms of live animalculæ 0 1 m.m. in length.

NOTTINGHAM SEWAGE FARM, 1899.

Sewages and Effluents.

No. of Sample	10	11	12	13
Nature of Sample	Screened and Crude Sewage (heavy rain on the preceding day).	Final Effluent from field No. 39 (this had been heavily over-sewaged intentionally).	Final Effluent off fields Nos. 9, 19 and 12.	Screened and Crude Sewage.
Drawn	Tuesday, 5th Dec. 1899, 12 noon.	Tuesday, 5th Dec. 1899, 1.30 p.m. (heavy rain on preceding night).	Tuesday, 5th December 1899, 1.35 p.m.	Tuesday, 12th Dec. 1899, 12.15 noon.
Temperature of sample	15·0° C. (59° F.)	8·9° C. (48° F.)	11·1° C. (52° F.	15·0° C. (59° F.)
Temperature of air	9·4° C. (49° F.)	—	—	—
If jointed or incubated	—	—	—	—
Analysed	8th December 1899.	7th December 1899.	7th Dec. 1899.	15th December 1899.
Parts per 100,000, *by weight.*				
Ammoniacal nitrogen (a) by direct Nesslerization.	Not practicable.	0·63 approx.	0·021 approx. (very turbid.)	Not noted.
Ammoniacal nitrogen (b) by distillation.	3·21	0·84	0·015	3·62
Albuminoid nitrogen	1·45	0·37	0·016	2·63
Nitrous nitrogen	None.	None.	None.	None.
Nitric nitrogen	Not done.	0·01 (?)	1·618	Not done.
Total nitrogen, by Kjeldahl, *with* reduction (after correction for nitrite).	4·68	1·26	1·670*	7·86
Blank	(0·28 in 7·80)	(0·28 in 2·31)	(0·28 in 2·51)	(0·41 in 13·03)
Correction for nitrite	None.	None.	None.	None.
"X" nitrogen	0·02 (?)	0·04	0·021	1·61
Organic nitrogen, by Kjeldahl, *with* reduction.	1·47 (?)	0·41	0·037	4·24
Organic nitrogen, by Kjeldahl, *without* reduction: Taking ammonia by distillation	1·69	0·43	0·071	1·90
Oxygen absorbed from permanganate at 26·7° C. (80° F.) *at once.*	4·97	0·44	0·078	10·76
,, ,, ,, *after four hours.*	20·56	2·23	0·188	25·06
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.) *at once.*	—	—	—	—
,, ,, ,, *after four hours.*	—	2·19	0·157	—
Smell after incubation	—	Strong sulphide. Slight blackening.	No smell.	—
Chlorine	9·66	12·50	11·40	23·42
Gases: parts per 1,000, *by volume.*			Spare bottle; jointed 7th, analysed 7th Dec. 9th.	
Carbon Dioxide (free)	—	57·81	65·60 65·46	—
Oxygen (boiled out)	—	0·16	20·95 4·98	—
Nitrogen	—	21·58	20·95 15·77	—
Remarks	Contained much dark-brown sediment. Alkaline.	Pale yellow liquid with a good deal of brown sediment. Distinct sewage smell. Very slightly alkaline. Much lime and much sulphate in solution. *Note.*—From 9th November this field had been sewaged night and day for 14 days; after that, night sewage only.	Clear and colourless. No sediment. No smell. Distinctly alkaline. Much lime. Much sulphate. (*) This 'Kjeldahl' done about a week later; original estimation much too low.	This sample had a copious brown deposit. There was dye refuse in it. Alkaline.

NOTTINGHAM SEWAGE FARM, 1899.

Effluents.

14	15	16	18	19
FINAL EFFLUENT from same field as No. 11, but since 5th December only night sewage had been run on to it.	FINAL EFFLUENT from same source as No. 12.	FINAL EFFLUENT, corresponding to Sewage No. 13.	FINAL EFFLUENT from same source as Nos. 12 and 15.	FINAL EFFLUENT from Field No. 63.
Tuesday, 12th December 1899, noon.	Tuesday, 12th December 1899, 12.30 noon.	Tuesday, 12th Dec. 1899, 3.15 p.m.	Wednesday, 20th Dec. 1899, 4 p.m.	Wednesday, 20th Dec. 1899, 4 p.m.
9·4° C. (49° F.)	9·4° C. (49° F.)	10·0° C. (50° F.)	10·0° C. (50° F.)	10·0° C. (50° F.)
14th December 1899.	15th December 1899.	14th December 1899.	22nd December 1899.	22nd December 1899.
Turbid.	Turbid.	Turbid.	Turbid.	Turbid.
0·044	0·011	0·275	0·016	0·289
0·026	0·016	0·049	0·027	0·101
0·007	None.	0·018	None.	0·019
2·302	1·653 { Probably too low. }	1·806	1·598	2·061
2·334	1·875	2·223	1·651	2·154
(0·41 in 4·15)	(0·28 in 3·29)	(0·28 in 3·83)	(0·28 in 2·93)	(0·41 in 3·85)
say 0·004	None.	0·011	None.	0·011
None (— 0·073)	0·195†	0·075	0·010	None (— 0·308) (?)
0·026	0·211†	0·124	0·037	0·101 (?)
0·045	0·055	None (— 0·063)	0·037	0·054
0·031	Too small to measure.	0·094	0·031	0·016
0·266	0·125	0·314	0·125	0·251
—	—	—	—	—
0·282	0·141	0·580	0·062 (17 days).	0·298 (17 days).
No smell.	No smell.	No smell.	No smell.	Sweet.
12·48	11·32	12·56	11·20	12·56
57·59	54·31	60·28	164·93 { Free and combined. }	197·40 { Free and combined.
5·76	5·74	4·55	5·74	4·72
16·09	15·97	15·99	15·97	16·17
Beautifully clear and bright. Small speck of flocculent matter. Slightly alkaline. Much lime. Much sulphate.	Clear and colourless. No suspended matter. No smell. Very slowly alkaline. A great deal of lime and much sulphate. †These figures are obviously far too high.	Clear and colourless. No suspended matter. No smell. Slowly but distinctly alkaline. A great deal of lime and of sulphate in solution.	Clear and colourless. No suspended matter. No smell. Very slowly alkaline. A great deal of lime and much sulphate.	Clear and colourless. No suspended matter. No smell, but earthy upon warming. A great deal of lime and much sulphate.

NOTTINGHAM SEWAGE FARM, 1900.

Sewage and Effluents.

No. of Sample	109	110	111	111
Nature of Sample	Screened and Crude Sewage.	Final Effluent corresponding to Sewage No. 109.	Final Effluent from same source as No. 110.	Duplicate Sample.
Drawn	Monday, 23rd July 1900, 11.55 a.m.	Monday, 23rd July 1900, 2.15 p.m.	Tuesday, 24th July 1900, 3 p.m.	Tuesday, 24th July 1900, 3 p.m.
Temperature of sample	20° C. (68° F.)	11·7° C. (53° F.)	11·7° C. (53° F.)	——
Temperature of air	25° C. (77° F.)	24·4° C. (76° F.)	27·8° C. (82° F.)	——
If jointed or incubated	——	——	——	Jointed, 25th July.
Analysed	24th July 1900.	24th July 1900.	25th July 1900.	3rd August 1900.
Parts per 100,000 *by weight.*				(A.) (B.)
Ammoniacal nitrogen (a) by direct Nesslerization.	Turbid.	Turbid.	Turbid.	——
Ammoniacal nitrogen (b) by distillation.	5·32	0·28	0·23	——
Albuminoid nitrogen	1·83	0·03	0·04	——
Nitrous nitrogen	None.	None.	0·01	2·83 2·95
Nitric nitrogen	Not done.	2·99	3·28	
Total nitrogen by Kjeldahl, *with* reduction (after correction for nitrite).	7·19	3·38	3·45	——
Blank	(0·19 in 5·29.)	(0·16 in 4·95.)	(0·19 in 5·07.)	——
Correction for nitrite	None.	None.	+ 0·01	——
"X" nitrogen	* 0·04 (?)	0·08	None (— 0·11.)	——
Organic nitrogen, by Kjeldahl, *with* reduction	* 1·87 (?)	0·11	0·04	——
Organic nitrogen, by Kjeldahl, *without* reduction:				
Taking ammonia by distillation	3·03	0·03	0·03	——
Oxygen absorbed from permanganate at 26·7° C. (80° F.) *at once.*	4·22	Nil.	Nil.	——
" " " *after four hours.*	10·97	0·09	0·10	——
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.) *at once.*	——	0·11 (Six days. Temperature of incubator low on two days.)	0·13	——
" " " *after four hours.*	——	0·22	0·31	——
Smell after incubation	——	Sweet.	Sweet.	——
Chlorine	17·96	11·94	11·84	——
Gases: parts per 1,000, *by volume.*				
Oxygen (by cuprous chloride):				
When sample was analysed	——	5·5 approx.	3·0 approx.	1·6
Remarks	This sample contained a moderate amount of black and brown deposit. Sewage smell. Alkaline. *These figures are clearly wrong.	As clear and colourless as tap water. No suspended matter. No smell. Alkaline.	Clear, bright and colourless. Either no smell or earthy. A few greenish flocculent particles. Strongly alkaline.	There has been only a small absorption of dissolved oxygen here.

NOTTINGHAM SEWAGE FARM, 1900.

Sewage and Effluents.

113	114	115	116	119	118
FINAL EFFLUENT from same source as Nos. 110 and 111, after three days' sewaging.	SCREENED AND CRUDE SEWAGE.	FINAL EFFLUENT corresponding to Sewage No. 114.	EFFLUENT from same source as No. 115.	FINAL EFFLUENT from same source as No. 115.	FINAL EFFLUENT from Night Sewage.
Wednesday, 25th July 1900, 11.45 a.m.	Monday, 30th July 1900, 12.15 noon.	Monday, 30th July 1900, 2.15 p.m.	Tuesday, 31st July 1900, 11.45 a.m.	Wednesday, 1st August 1900, 11.45 a.m.	Wednesday, 1st August 1900, 11.30 a.m.
11·7° C. (53° F.)	19·4° C. (67° F.)	10·6° C. (51° F.)	10·6° C. (51° F.)	10·6° C. (51° F.)	12·8° C. (55° F.)
27·8° C. (82° F.)	16·7° C. (62° F.)	20·0° C. (68° F.)	20·0° C. (68° F.)	20·0° C. (68° F.)	20.0° C. (68° F.)
—	—	—	—	—	—
26th July 1900.	1st August 1900.	1st August 1900.	—	2nd August 1900.	2nd August 1900.
	(A.) (B.) Same Bottle.			(A.) (B.) Separate Bottles.	
Turbid.	— —	Turbid.	—	Turbid. Turbid.	—
0·21	3·24 3·78	0·05	—	0·03 0·03	0·15
0·03	1·07 1·29	0·03	—	0·01 0·01	0·03
0·01	Slight trace. None.	Trace.	—	0·01 0·01	0·01
2·80 {Probably low.}	Not done.	1·78	—	1·63 1·70	1·83
3·41	5·81 5·38	1·90	—	1·93 1·94	2·18
(0·16 in 4·98.)	(0·19 in 4·31; 0·37 in 4·14.)	(0·16 in 2·86.)	—	(0·19 in 2·91; 0·13 in 2·83.)	(0·16 in 3·24.)
+ 0·01	None.	None.	—	+0·01 +0·01	+ 0·01
0·26 {These figures are of course too high.}	1·50 0·31	0·04	—	0·25 (?) 0·19 (?)	0·16
0·29	2·57 1·60	0·07	—	0·26 (?) 0·20 (?)	0·19
None (— 0·17).	—	0·02	—	0·02 0·06	0·08
0·07	5·11 —	0·01	—	0·16 —	0·14
0·25	13·96 —	0·95	—	0 22 —	0·37
0·13 } Six days.	—	0·07 } Six days.	—	0·19 } Six days.	0·25
0·40	—	0·17	—	0·16	0·38
Sweet.	—	Slight earthy.	—	Sweet.	Sweet.
11·94	— 14·36	11·30	—	11·24 11·45	11·84
4·3	—	5·9	—	5·25	4·8
Clear and colourless. No suspended matter. No smell. Strongly alkaline.	This sewage contained a moderate amount of loose dark-brown sediment, besides some tea leaves (which were rejected for the analyses). Sewage smell. Strongly alkaline. *Note.*—(A.) and (B.) were two different workers. Even allowing for discrepancies in sampling, the above results do not agree very well, but they may be given here. The average of the figures is taken.	Clear and colourless. The only suspended matter was one small worm. No smell. Strongly alkaline.	This bottle arrived broken. The liquid was clear.	As clear and colourless as tap water. No smell. Strongly alkaline.	Clear and colourless. A few minute greenish particles. No smell. Strongly alkaline.

NOTTINGHAM SEWAGE FARM, 1900–1901.

Effluents.

No. of Sample	No. 121		121		332	332
Nature of Sample	General Effluent.		Duplicate.		General Effluent.	Small Duplicate.
Drawn	Monday, 6th August 1900, 11.45 a.m.		—		Monday, 23rd September 1901, 2.45 p.m.	—
Temperature of sample	12·8° C. (55° F.)		—		13·3° C. (56° F.)	—
Temperature of air	15·0° C. (59° F.)		—		19·4° C. (67° F.)	—
If jointed or incubated	—		Jointed, 7th August.		—	Jointed and incubated, 25th September.
Analysed	7th August 1900.		16th August 1900.		25th September 1901.	10th October 1901.
	(A.)	(B.)	(A.)	(B.)		
Parts per 100,000, *by weight.*	Separate Bottles.					
Ammoniacal nitrogen (a) by direct Nesslerization.	Turbid.	Turbid.	—		—	—
Ammoniacal nitrogen (b) by distillation.	0·04	0·04	—		—	—
Albuminoid nitrogen	0·02	0·02	—		—	—
Nitrous nitrogen	Heavy trace.	Trace.	1·30	1·38	Mere trace.	—
Nitric nitrogen	1·25	1·25			1·71	—
Total nitrogen, by Kjeldahl, *with* reduction (after correction for nitrite).	1·41	1·54	—		—	—
Blank	(0·16 in 2·09; 0·13 in 2·30).		—		—	—
Correction for nitrite	None.		—		—	—
"X" nitrogen	0·10	0·23(?)	—		—	—
Organic nitrogen, by Kjeldahl, *with* reduction.	0·12	0·25(?)	—		—	—
Organic nitrogen, by Kjeldahl, *without* reduction: Taking ammonia by distillation	0·06	0·06	—		—	—
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once.*	0·02	—	—		0·11	—
" " " *after four hours.*	0·07	—	—		0·28	—
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once.*	Nil.	—	—		0·19 seven days.	—
" " " *after four hours.*	0·12	—	—		0·46 seven days.	
Smell after incubation	Sweet.	—	—		Sweet.	No smell.
Chlorine	7·10*	9·20*	—		—	—
Parts per 100,000, *by volume.*						
Solids by centrifuge	—		—		37·0	—
Gases: parts per 1,000, *by volume.*						
Oxygen (by cuprous chloride)	6·1	—	6·2	—	2·7, 2·8 Two observers.	Just over 1·0
Remarks	Very slightly opalescent. A few greenish flocculi. No smell. Strongly alkaline. * There has been clearly a mistake in one of these figures for chlorine.		This sample has undergone no change during the last week, though the weather was warm.		Clear and colourless, with a little reddish-brown flocculent sediment (obviously washed out from the drains). No smell. Alkaline.	After incubation this was a clear, colourless liquid, but containing a fair quantity of red-brown flocculent particles. No smell. Alkaline. Incubation had only caused this to lose a very little dissolved oxygen.

NOTTINGHAM SEWAGE FARM, 1900–1901.

Effluents.

333 General Effluent.	333 Small Duplicate.	340 General Effluent.	340 Small Duplicate.	341 General Effluent.	341 Small Duplicate.
Tuesday, 24th September 1901, 11.30 a.m.	—	Wednesday, 25th September 1901, 4.15 p.m.	—	Thursday, 26th September 1901, 11.30 a.m.	—
13·3° C. (56° F.)	—	12·8° C. (55° F.)	—	18·9° C. (66° F.)	—
15·6° C. (60° F.)	—	16·7° C. (62° F.)	—	18·9° C. (66° F.)	—
—	Jointed and incubated, 25th September.	—	Jointed and incubated, 26th September.	—	Jointed and incubated, 28th September.
27th September 1901.	11th October 1901.	26th Sept. 1901.	11th October 1901.	28th Sept. 1901.	11th October 1901.
—	—	—	—	—	—
—	—	—	—	—	—
—	—	—	—	—	—
None.	—	None.	0·10	None.	—
1·55	—	1·27	0·76	1·24	—
—	—	—	—	—	—
—	—	—	—	—	—
—	—	—	—	—	—
—	—	—	—	—	—
—	—	—	—	—	—
—	—	—	—	—	—
None.	—	None.	—	0·03	—
0·21	—	0·50	—	0·52	—
0·18 0·37	—	0·15 } six 0·39 } days.	—	0·15 0·28	— —
Not noted, but must have been sweet.	No smell.	Sweet.	No smell.	Sweet.	Not noted, but sweet (no doubt).
—	—	—	—	—	—
34·0	—	Less than 25·0	—	Less than 27·0	—
2·8	1·2	2·5	0·7	2·2	About 1·2
Very clear and colourless. Not much sediment, which was red-brown in colour. No smell. Alkaline.	After incubation, clear and colourless, with a fair amount of red-brown flocculent sediment. No smell. Alkaline. Here again incubation had caused the loss of but very little oxygen.	Clear, colourless liquid, but with apparently a fair amount of red-brown flocculent sediment. No smell. Alkaline	After incubation this was a clear, almost colourless liquid, with red-brown sediment. No smell. Alkaline. *Note.*—It is curious that there should be any oxygen left here, with the nitrate so much reduced. Possibly the solid flocculent matter in the lower part of the bottle reduced some nitrate in its immediate neighbourhood, before the dissolved oxygen in the upper layer of liquid was exhausted.	Very slightly turbid colourless liquid. Not much red-brown sediment. No smell. Alkaline.	After incubation this was a very slightly brown, clear liquid with some red-brown sediment. Alkaline.

NOTTINGHAM SEWAGE FARM, 1900.

River Water.

No. of Sample	112		117		120	
Nature of Sample	Trent River Water *above* Effluent Outfall.		Trent River Water *above* Effluent Outfall.		Trent River Water above Junction with Effluent.	
Drawn	Tuesday, 24th July 1900, 4 p.m.		Tuesday, 31st July 1900, 12.30 noon.		Monday, 6th August 1900, 11.30 a.m.	
Temperature of sample	22·2° C. (72° F.)		18·9° C. (66° F.)		14·4° C. (58° F.)	
Temperature of air	27·8° C. (82° F.)		21·7° C. (71° F.)		14·4° C. (58° F.)	
If jointed or incubated	Jointed 25th July.		Jointed 1st August.		——	
Analysed	9th August 1900.		15th August 1900.		9th August 1900.	
	(A)	(B)	(A).	(B).	(A).	(B).
Parts per 100,000, *by weight.*					Separate Bottles.	
Ammoniacal nitrogen (a) by direct Nesslerization.	——		——		Turbid.	Not noted.
Ammoniacal nitrogen (b) by distillation	——		——		0·06	0·06
Albuminoid nitrogen	——		——		0·08	0·03
Nitrous nitrogen	0·27	0·28	0·36	0·48	0·02	0·01
Nitric nitrogen					0·21	0·25
Total nitrogen by Kjeldahl, *with* reduction (after correction for nitrite).	——		——		0·38	—
Blank	——		——		(0·16 in 0·68)	—
Correction for nitrite	——		——		+0·01	—
"X" nitrogen	——		——		0·01	—
Organic nitrogen by Kjeldahl, *with* reduction.	——		——		0·09	—
Organic nitrogen by Kjeldahl, *without* reduction:						
Taking ammonia by distillation	——		——		0·17	—
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once.*	——		——		0·30	0·58
" " " *after four hours*	——		——		1·19	1·46
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once.*	——		——		0·20	Six days. 0·33
" " " *after four hours*	——		——		1·20	1·14
Smell after incubation	——		——		Sweet.	Not noted.
Chlorine	——		——		4·30	4·20
Gases: parts per 1,000, *by volume.*						
Oxygen (by cuprous chloride):						
When analysed	—	1·0	4·0	—	4·5	—
Remarks	All the dissolved oxygen has not been exhausted.		This sample has kept its oxygen well.		Very slightly opalescent, with a considerable brown deposit. No smell. Alkaline.	

Note.—(A) and (B) were two different workers. It will be noticed that some of the above duplicate analyses do not agree well in certain respects. Even taking into account the fact that separate bottles of the samples were examined, it is evident that the "personal equation" has had some influence here, *i.e.*, the albuminoid is in three instances out of four higher in (A) than in (B), and the 4-hours "oxygen absorbed" lower.

NOTTINGHAM SEWAGE FARM, 1900.

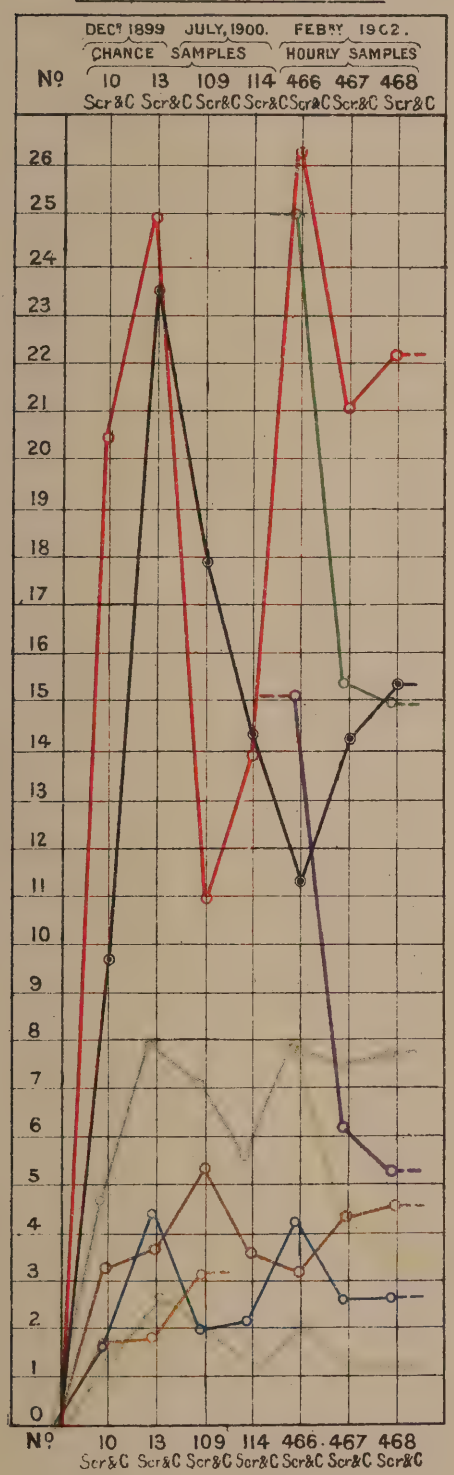
River Water alone and admixed with Effluent.

120	121	122	123	123
DUPLICATE SAMPLE.	GENERAL EFFLUENT.	RIVER WATER AND EFFLUENT MIXED. (River high.) Drawn 50 yards below Effluent No. 121.	RIVER WATER AND EFFLUENT MIXED. (River high.) Drawn 120 yards lower down than Sample No. 122.	DUPLICATE SAMPLE
—	Monday, 6th August 1900, 11.45 a.m.	Monday, 6th August 1900, 12 noon.	Monday, 6th August 1900, 12.30 noon.	—
—	12·8° C. (55° F.)	14·4° C. (58° F.)	14·4° C. (58° F.)	—
—	15·0° C. (59° F.)	13·9° C. (57° F.)	13·3° C. (56° F.)	—
Jointed 7th August	—	—	—	Jointed 7th August.
15th August 1900.	7th August 1900.	8th August 1900.	8th August 1900.	17th August 1900.
(A). (B). Same Bottle.	(A), (B). Separate Bottles.	(A). (B.) Separate Bottles.	(A). (B). Separate Bottles.	(A). (B). Same Bottle.
—	Turbid. Turbid.	Turbid. Turbid.	Turbid. Turbid.	—
—	0·04 0·04	0·06 0·05	0·06 0·05	—
—	0·02 0·02	0·08 0·04	0·08 0·05	—
} 0·30 } 0·34	Heavy trace. Trace.	0·02 0·02	0·02 0·02	} Lost 0·28
	1·25 1·25	0·25 0·29	0·19 0·15	
—	1·41 1·54	0·48 0·47	0·43 0·44	—
—	(0·16 in 2·09; 0·13 in 2·30).	(0·16 in 0·83; 0·13 in 0·78).	(0·19 in 0·78; 0·13 in 0·73).	—
—	None. None.	+0·01 +0·01	+0·01 +0·01	—
—	0·10 0·23 (?)	0·07 0·07	0·08 0·17	—
—	0·12 0·25 (?)	0·15 0·11	0·16 0·22	—
—	0·06 0·06	0·13 0·18	0·15 0·16	—
—	0·02 —	0·30 0·69	0·37 0·87	—
—	0·07 —	1·14 1·60	1·33 1·50	—
—	Nil. —	0·12 } Six 0·58	0·21 } Six 0·44	—
—	0·12 —	0·89 } days. 1·02	1·02 } days. 1·24 (4½ hours).	
—	Sweet. —	Sweet. Not noted.	Sweet. Not noted.	—
—	7·10* 9·20* * Cannot account for this discrepancy; one figure must be wrong.	4·0 4·1	3·54 3·95	—
1·20 —	6·1 —	4·8 —	4·7 —	0·7 —
This sample appears to be much the same in quality as Sample No. 112.	Very slightly opalescent, with a few greenish flocculi. No smell. Strongly alkaline.	Opalescent, with considerable brownish and somewhat granular deposit. Slight earthy smell. Alkaline.	Opalescent, with considerable brownish deposit. No smell, or only a slight earthy one. Alkaline.	Between 7th and 17th August the weather was warm. The dissolved oxygen has been pretty nearly exhausted here.

Diagram No. 34.

NOTTINGHAM SEWAGE FARM.

SEWAGES. CURVES.



Nature of Sewage

Scr & C = *Screened & Crude*

REFERENCE

Parts per 100.000, by Weight.

Albuminoid Nitrogen ..... *Shewn thus*

Organic Nitrogen by Kjeldahl, with Reduction .....

Organic Nitrogen by Kjeldahl, without Reduction .....

Ammoniacal Nitrogen .....

Total Nitrogen by Kjeldahl, with Reduction .....

"Oxygen absorbed" from Permanganate at 26·7°C (80°F.) in four hours .....

Chlorine (Combined) .....

Solids in suspension (Gravimetrically) (Scale divided by 10) .....

Cellulose .....

Cellulose (still containing fat) .....

Note

Figures in the Vertical line represent "Parts per 100.000."

Figures in the Horizontal line represent the numbers of the Samples analysed.

A dotted line is used when there is a break in the curve.

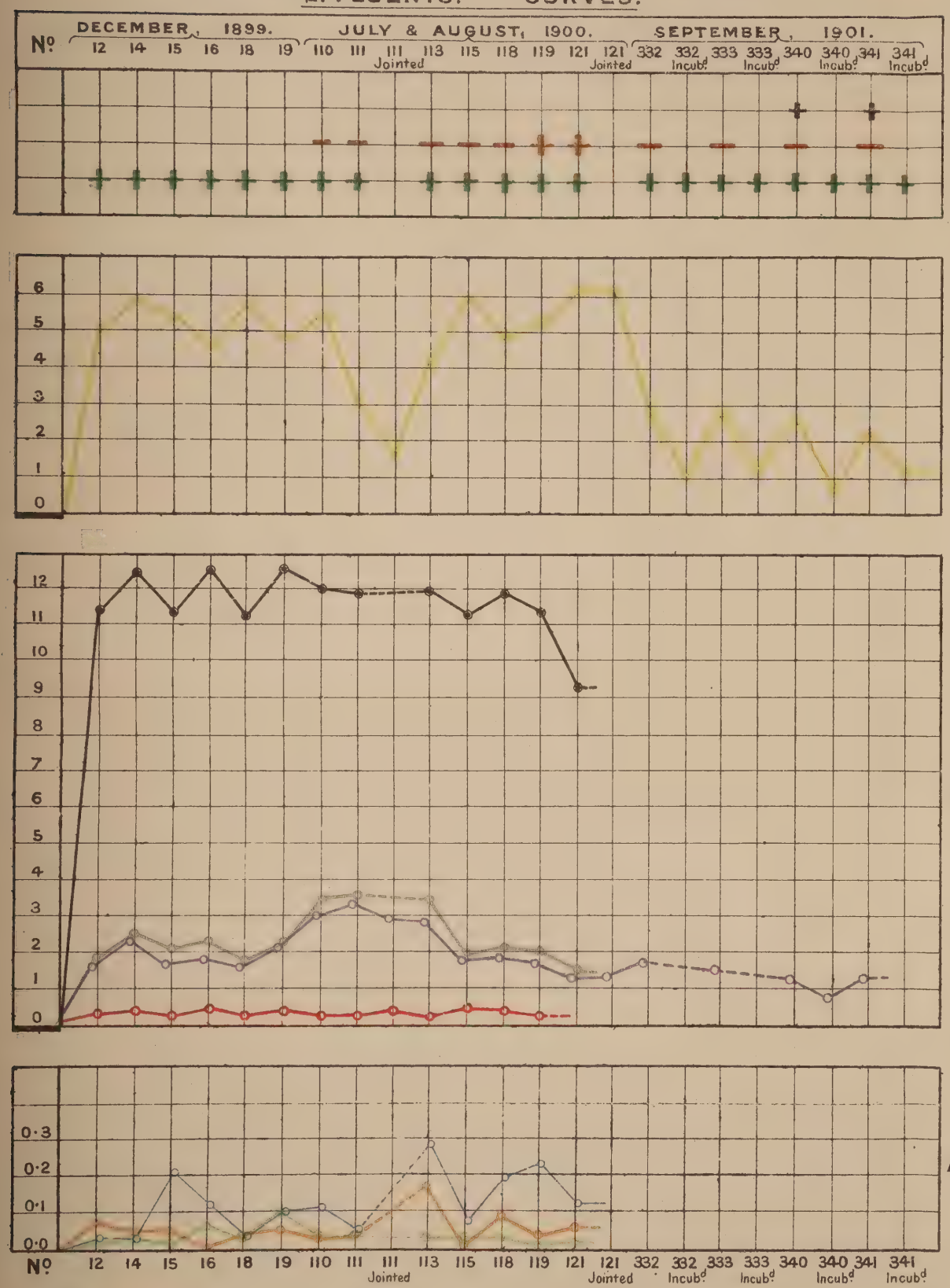
3332. 8. 32

Waller & Graham, Ltd Litho. London

Diagram No. 35.

NOTTINGHAM SEWAGE FARM.

EFFLUENTS. CURVES.



REFERENCE

Smell of Samples when drawn Shewn thus + or —

Scudder's Incubation Test + —

Incubation test as judged by Smell + —

Parts per 1000, by Volume (C.C. per Litre)

Dissolved Oxygen when sample was analysed Shewn thus

Parts per 100.000. by Weight.

Total Nitrogen by Kjeldahl, with Reduction. Shewn thus

Nitric + Nitrous Nitrogen (together)

"Oxygen absorbed" from Permanganate at 26·7°C (80°F.) in four hours.

Chlorine (Combined)

Parts per 100.000, by Weight.

Albuminoid Nitrogen Shewn thus

Organic Nitrogen by Kjeldahl, with Reduction.

Organic Nitrogen by Kjeldahl, without Reduction.

Note

"Jointed" Indicates a sample jointed and allowed to stand at laboratory temperature.

"Incubated" Indicates a sample jointed and allowed to stand for five days or longer at a temperature of 26.7°C (80°F.).

Note

Figures in the Vertical line represent "Parts per 100.000."

Figures in the Horizontal line represent the numbers of the Samples analysed.

A dotted line is used when there is a break in the curve.

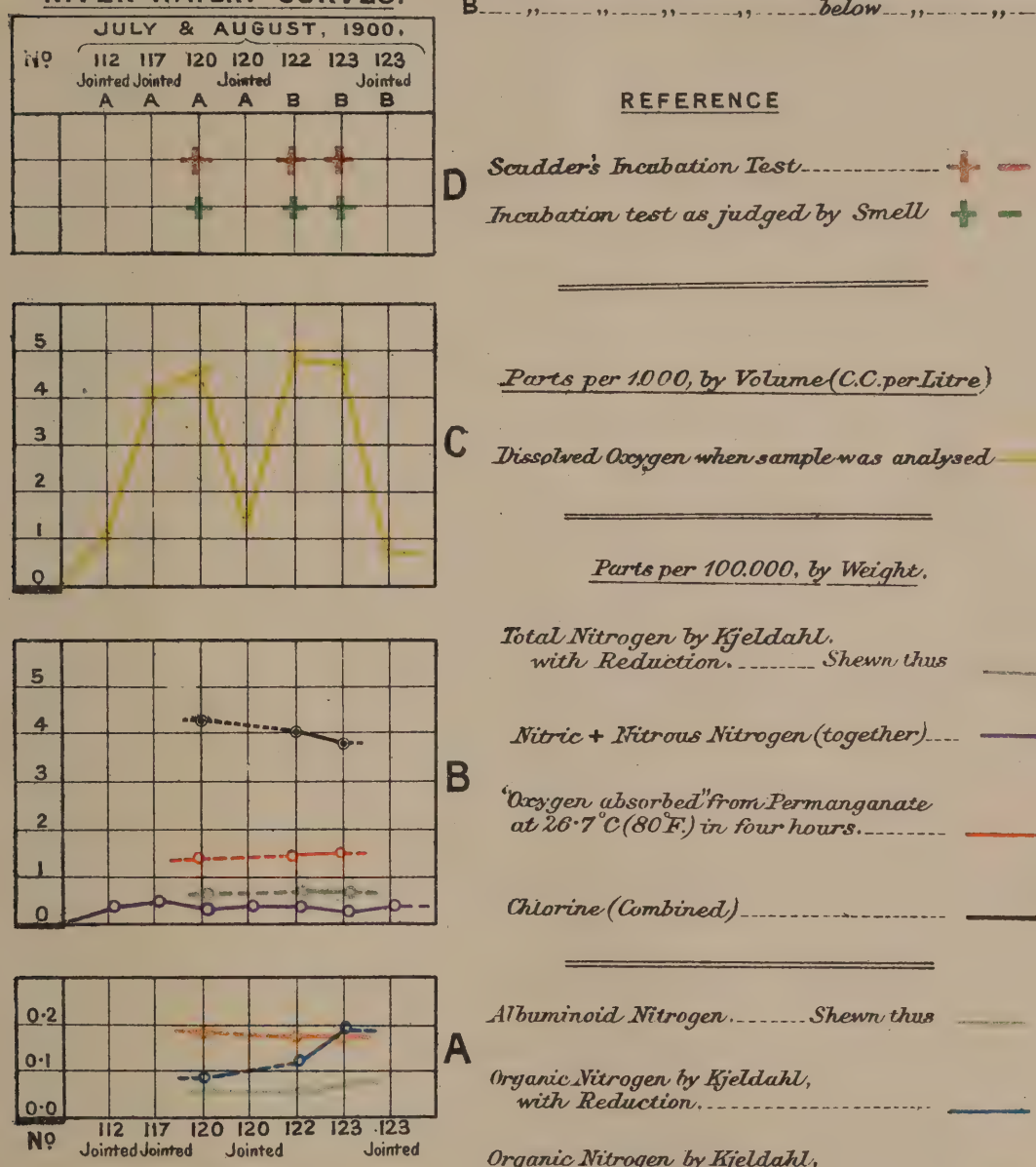
3332. 8. 02.

Weller & Graham Ltd Litho. London.

Diagram No. 36.

NOTTINGHAM SEWAGE FARM.

RIVER WATER. CURVES.



Note.
A Indicates a sample drawn from above Effluent Outfall.
B ---- ,, ---- ,, ---- ,, ---- ,, ---- below ---- ,, ---- ,, ----

REFERENCE

Scudder's Incubation Test ---------- + −

Incubation test as judged by Smell + −

Parts per 1000, by Volume (C.C. per Litre)

Dissolved Oxygen when sample was analysed

Parts per 100.000, by Weight.

Total Nitrogen by Kjeldahl, with Reduction. ------- Shewn thus

Nitric + Nitrous Nitrogen (together) ----

"Oxygen absorbed" from Permanganate at 26·7°C (80°F.) in four hours. --------

Chlorine (Combined) ----------

Albuminoid Nitrogen. ------- Shewn thus

Organic Nitrogen by Kjeldahl, with Reduction. ----------

Organic Nitrogen by Kjeldahl, without Reduction. ----------

Note.
Figures in the Vertical line represent "Parts per 100.000."

Figures in the Horizontal line represent the numbers of the Samples analysed.

A dotted line is used when there is a break in the curve.

Note.
"Jointed" Indicates a sample jointed and allowed to stand at laboratory temperature.

3332. 8. 02.

Weller & Graham, Ltd Litho. London.

RUGBY (HIGH LEVEL) SEWAGE FARM.

Chemical Report.

1. Situation of farm.—New Bitton, about one mile from Rugby.
2. Total acreage of farm.—40 acres.
3. Total irrigable area.—35 acres.
4. Average area irrigated at one time.—7 acres.
5. Population draining to farm.—6,000.
6. Population per acre irrigated.—171.
7. Gallons of sewage per head per day.—50.
8. Dry weather flow of sewage per 24 hours.—300,000 gallons.
9. Gallons of sewage treated per acre per 24 hours.—42,850.
10. Gallons of sewage treated per acre per 24 hours, on the assumption that each acre of the irrigable area is under sewage all the time.—8,500.
11. Character of the sewage.—Mainly domestic.
12. Method of treatment.—Screening and settling for the most part, but with a little chemical precipitation. Surface irrigation and filtration combined, but the former predominating.
13. General character of the soil and subsoil.—Heavy loam overlying stiff clay.
14. Separate or combined sewerage system.—Partially separate.
15. The final effluent is discharged into—River Avon.
16. Number of years farm in operation (before 1900).—33 years.

RUGBY HIGH LEVEL SEWAGE FARM

This farm, like those at Beddington and South Norwood, is an old one, having been started 35 years ago (from 1902), and, like them, it is interesting from the fact of a few observations having been made there by the Rivers Pollution Commission of 1868 (Vol. 1, First Report, pp. 79–80). Only two analyses of effluents are cited in the Report of that Commission, one of these being a final effluent, which was good.

The total area of irrigable land is 35 acres, of which about 7 acres are sewaged at one time. It will be noticed that this ratio (35 : 7) is a high one. The whole of the land is cropped at one time or another.

The farm is drained at an average depth of 3′ 9″, and, in addition, there are some old land drains 18″ below the surface (cf. Part IV. : Engineering and Practical Report).

The effluents are partly surface and partly filtration effluents, but more surface than filtration (cf. temperatures of effluents ; also diagrams of temperatures of effluents throughout the year, as given in the Engineering Report. In those diagrams the temperature differences between filtration and surface effluents are seen to be very striking).

It may be well to draw attention again here to what has already been explained in some detail by Mr. Kershaw, viz., to the fact that the Rugby High Level Farm system is different to that of any other farm which has been under observation by the Commission. Half of the (settled) sewage is treated on a *relatively* large plot of ground (A), and the effluent from this is mixed with the other half of the sewage, the mixture then passing over (and through) a second smaller plot of ground (B). Roughly speaking, the areas of A and B are as $2\frac{1}{2} : 1$. The second half of the sewage is thus blended with an equal volume, or thereabouts, of a partially purified liquid, which is already to some extent aerated and nitrated. It would be very interesting to compare over a sufficiently long period of time the results given by equal quantities of the same sewage treated partly in this way and partly in the usual way (*i.e.*, over two fields, one after the other).

Soil and Subsoil.

The surface soil is a heavy loam about 10″ deep, and it overlies yellow clay, but pot-holes of gravel occur in places.

The mechanical composition of this soil, carefully sampled to represent as true an average as possible, is given in the following table :—

Name of Fraction.	Surface Soil, Per Cent.			Sub-soil, Per Cent.		
	Not Ignited.	Ignited.	Difference.	Not Ignited.	Ignited.	Difference.
"Gravel" (above 8·0 m.m. diameter) - -	—	—	—	—	—	—
Fine "Gravel" (above 2·0 m.m. diameter) -	3·31	3·17	0·14	—	—	—
Coarse "Sand" (above 1·0 m.m. diameter) -	1·13	1·04	0·09	—	—	—
Coarse "Sand" (above 0·5 m.m. diameter) -	1·18	1·13	0·05	—	—	—
Medium "Sand" (above 0·25 m.m. diameter)	2·06	1·96	0·10	—	—	—
"Sand" (0·25 to 0·05 m.m.) - - -	36·74	35·91	0·83	—	—	—
"Silt" (0·05 to 0·01 m.m.) - - -	25·51	21·88	3·63	—	—	—
"Dust" (from 0·01 m.m. downwards, which settles from water in 24 hours) - -	21·44	18·29	3·15	—	—	—
"Clay" (*i.e.*, the still finer residue precipitated from water by dilute nitric acid) -	7·40	6·46	0·94	—	—	—
Loss on ignition (separate determination) -	—	9·24	—	—	—	—
	98·77	99·08	7·93			
Real specific gravity of soil dried at 110° C.	2·595	—	—	—	—	—
Apparent specific gravity - - - -	1·74 1·63 1·68	—	—	—	—	—
Weight of water retained by 100 grammes of the soil when fully drained - - -	55·9 ?	—	—	—	—	—
Number of particles in 1 gramme of the ignited soil (approx.) - - - - -	3,207,341,170		—	—	—	—
Number of particles in 1 c.c. of the ignited soil (approx.) - - - - - -	5,384,971,060		—	—	—	—
Parts per 100,000.						
Lime dissolved by water in 24 hours - -	0·051	—	—	0·071	—	—
Lime dissolved by water saturated with carbonic acid, in 48 hours - - - - -	0·482	—	—	0·969	—	—

For a discussion of the figures given in this table, the reader is referred to the Section upon Soils : page 275.

Volume treated per acre, etc.

As already stated in the Engineering Report,* only a part of the Rugby sewage is treated on this farm. The sewage is domestic, with this exception—that it contains a large quantity of oil from an engine works, which is skimmed off twice a day from the surface of the settling tanks, because of the injury that it formerly caused to the growing rye grass when it was allowed to run on to the land.

The dry-weather flow of sewage is 300,000 gallons, and the population draining to the farm about 6,000; hence the flow per head is 50 gallons—a very high figure. Since the water supply is only 26·5 gallons, half of the sewage must consist of subsoil water which finds its way into the sewers.

The number of persons per acre irrigated is 171.

Mr. Kershaw states that there is not much subsoil water on the farm itself now.

The average area under irrigation at one time is 7 acres, an acre treating 42,850 gallons in 24 hours. But if we again assume, *for purposes of comparison*, that the whole irrigable area is under sewage continuously, *then each acre at Rugby treats 8,570 gallons per 24 hours all the year round.*

Nature of Sewage. (*Diagram No.* 37.)

The Rugby sewage is rather strong, though not quite so strong as the sewage at Aldershot Camp, and the samples throughout were alkaline, some of them very decidedly alkaline. The sewage arrives at the farm in a fairly fresh condition and not well broken up.

Eight chance samples, three of these screened and precipitated, Nos. 95, 99 and 101; one screened and settled, No. 224; and four crude, Nos. 93, 97, 233 and 235, were drawn; and three sets of average daily samples (screened and settled), drawn in equal quantities every hour during the 24 hours (Nos. 472, 473 and 474). Most of the samples had a sewage smell, but one (No. 233) smelt of soap, and another (No. 235) of paraffin mixed with sewage, while the three hourly samples had respectively a slight urine smell, a hippuric acid smell, and a smell like that of cattle urine. The temperature of these samples, drawn in the months of February and March, June and July, varied between 5·5° and 15° C. (42° and 59° F.).

As will be seen from the tables of analysis and the accompanying digest of the main figures of these analyses (see below), the averages of the chance samples in total nitrogen, organic nitrogen and "oxygen absorbed" are not very different from the same averages of the hourly sets of samples. But this must be an accident, seeing that the chance samples were partly crude, partly screened and precipitated, and partly settled. It will therefore be safer, in making any approximate calculations, to depend on the three sets of hourly samples of screened and settled sewage, both because this is the general treatment of the sewage on the farm, and also because no rain fell when these latter samples were being drawn.

As at the other farms, these hourly samples were taken—not according to rate of flow—but in equal quantities per hour throughout the 24 hours of the day, and the analytical figures will therefore probably represent a weaker sewage than is actually the case. But on the other hand the large influx of subsoil water into the sewers will—as Mr. Kershaw has pointed out—tend to counteract this, more subsoil water getting in at night, when the sewage flow is small and the sewage is weak, than during the day.

* Part IV.: Engineering and Practical Report.

The following is a summary of the more important analytical results :—

	Average.
Total Nitrogen—(*a*) 8 chance samples, partly screened and precipitated, partly screened and settled, and partly crude (2·80 to 14·94)	9·95
(*b*) 3 sets of hourly samples (9·39 to 9·99) - - - -	9·65
Ammoniacal Nitrogen (*a*) 8 chance samples, as above (1·95 to 11·21)	7·37
(*b*) 3 sets of hourly samples (5·74 to 6·46) - - - -	6·11
Total Organic Nitrogen—(*a*) 8 chance samples, as above (1·61 to 5·57)	2·54
(*b*) 3 sets of hourly samples (2·87 to 3·55) - - - -	3·29
Albuminoid Nitrogen—(*a*) 8 chance samples, as above (0·40 to 2·84)	1·49
(*b*) 3 sets of hourly samples (1·56 to 1·80) - - - -	1·73
"*Oxygen absorbed*" *in* 4 hrs, at 26·7° C. (80° F.)—(*a*) 8 chance samples, as above (3·55 to 33·31) - - - - - - - -	15·00
(*b*) 3 sets of hourly samples (17·55 to 19·18) - - - -	18·44
Chlorine—(*a*) 8 chance samples, as above (4·86 to 18·30) - -	11·68
(*b*) 3 sets of hourly samples (9·36 to 10·46) - - - -	9·99
Chlorine in the Water Supply - - - - - - -	2·30
Ratio of Ammoniacal Nitrogen to Chlorine, 3 sets of hourly samples - - - - - - {1 : 1·63, 1 : 1·57, 1 : 1·70} -	1 : 1·63
Ratio of Ammoniacal Nitrogen to Chlorine, after deducting the chlorine of the water supply,* 3 sets of hourly samples - - - - - {1 : 1·23, 1 : 1·21, 1 : 1·33} -	1 : 1·26
Chlorine in Subsoil Water - - - - - - - -	
Solids in Suspension, 3 sets of hourly samples (43·0 to 50·6) - -	47·30
Solids in Suspension, by Centrifuge (volumes) 3 sets of hourly samples (258 to 345) - - - - - - - - -	304·0 vols.
Ratio of Solids in Suspension to Centrifuge Solids {1 : 6·8, 1 : 6·4, 1 : 6·0} - -	1 : 6·4
Cellulose, still containing fat, 2 sets of hourly samples (12·96 and 20·96) (One extraction with dilute alkali and one with dilute acid.)	16·96
Ratio of Celluloses containing fat to Suspended Solids, 2 sets of hourly samples - - - - - {1 : 2·4, 1 : 3·3} -	1 : 2·9
Cellulose, 3 sets of hourly samples (5·88 to 7·92) - - - - (Extraction with alkali, acid, and ether.)	7·22
Ratio of Celluloses to Suspended Solids, 3 sets of hourly samples - - - - - - - {1 : 6·4, 1 : 6·1, 1 : 7·3} -	1 : 6·6

Few deductions can be drawn from the analyses of the various chance samples of sewage, excepting to note how widely they differ from one another. No. 95 (screened and chemically precipitated sewage) was an exceedingly dilute sample in every respect. Nos. 99 and 101 (also screened and precipitated) were, on the other hand, both strong, the first especially, but it would be hard to account for the great difference in chlorine in the two cases. Nos. 93, 97, 233 and 235 (crude sewages) varied greatly in strength, No. 93 being strong, No. 97 rather strong, No. 233 weak as regards nitrogen, and No. 235 strong (abnormally so as regards "oxygen absorbed"; it contained a very considerable quantity of brown sediment).

The three sets of hourly samples of *screened and settled sewage* were remarkably even in composition, containing an average of 9·7 parts total nitrogen, 3·29 parts

* The subsoil water, with which the sewage is diluted, no doubt contains less chlorine than this.

organic nitrogen (of which 1·73 was albuminoid), while the "oxygen absorbed" figure was 17·6. The suspended solids averaged 47 parts, which does not show good settlement.

The sewage which the Rugby high level farm has to treat may thus be classed as a rather strong one.

A few further points may be noted in connection with the annexed Tables of Analysis and Curves :—

The average ratio between albuminoid nitrogen and "oxygen absorbed" in the eight chance samples of sewage is 1 : 10·3, and in the three sets of hourly samples 1 : 10·9 ; but in the chance samples this ratio is very uneven, while in the hourly it is very even. That it should be so uneven in the chance samples is not surprising, seeing that they were partly crude, partly screened and precipitated, and partly screened and settled.

1. The *ratio between organic nitrogen and "oxygen absorbed"* in the hourly samples is distinctly lower than in the case of the Nottingham sewage, viz., 1 : 5·6, though this figure is itself rather higher than in the purely domestic sewages of Beddington, South Norwood, etc. The presence in the sewage of the oil already referred to has no doubt something to do with this.

2. The hourly samples still contained small but appreciable quantities of nitrate when analysed, which indicates the presence of subsoil water.

3. Excepting in the case of the very dilute sample, No. 233, the curves for the *total nitrogen and the organic nitrogen* corresponded well, while the albuminoid nitrogen and organic nitrogen curves followed one another very well indeed, the organic being nearly twice the albuminoid.

Again, the organic nitrogen as determined by *Kjeldahl* (a) with reduction, and (b) without reduction agreed fairly well, but the latter was in most cases the lower.

4. In the screened and settled sewages, the *"oxygen absorbed"* curve is of the same type as the various nitrogen curves and follows them very satisfactorily ; in the screened and precipitated sewages, the "oxygen absorbed" is relatively much less than before, but the curves still follow one another fairly ; and even in the crude sewages there is a partial agreement between these curves.

5. The similarity between the curve for *ammoniacal nitrogen* and that for *chlorine* is very marked in all the samples excepting No. 95 ; but when the chlorine curve is compared with the total nitrogen curve, it is seen that sometimes the one predominates and sometimes the other, though the types of curve are the same. Without, however, knowing something about the quantity of chlorine in the subsoil water, it is difficult to draw any accurate deductions here.

6. The *suspended solids* were somewhat coarse for a settled sewage.

The ratios between the *suspended solids* (a) estimated gravimetrically, and (b) volumetrically by centrifuge, are wonderfully constant in the hourly samples, the average being 1 : 6·4 ; and the same thing applies to the ratios between the cellulose and the suspended solids, the average figure being 1 : 6·6. In this screened and settled sewage, therefore, the centrifuge test (which can be carried out in a few minutes) would evidently give a valuable indication of the quantities both of the suspended solids themselves and of the cellulose in these solids.

1*st Field Effluents.* (*Diagram No.* 38.)

Eight of these were examined, one of them (No. 226) after incubation. The numbers of the samples were 99A, 101A, 94, 98, 226, 228, 236, and 238B. The first four were drawn in June and July, 1900, and the last four in February and March, 1901. Nos. 99A and 101A were from chemically precipitated, 94, 98 and 236 from crude, and the other three from settled sewage. Again, Nos. 99A, 101A, and 98 were partly surface and partly filtration effluents (this has been explained in the Engineering Report) ; Nos. 94, 226 and 228 were filtration effluents ; while Nos. 236 and 238B were surface effluents only.*

* The temperatures of the various effluents, however, when drawn, do not agree with this classification (surface or filtration), which must therefore be taken as being merely approximate, owing to the difficulty of the point.

These effluents were yellow in colour and either opalescent or turbid, some with little or no suspended matter, but two with much, viz., Nos. 226 and 236; the reaction was alkaline, or neutral to alkaline. They contained much lime and much sulphate in solution. The last five had a fishy-earthy smell when analysed, excepting No. 226, which had no smell.

The variations in temperature in those effluents, according to the season, were very marked. Thus the four drawn in summer varied between 13·8° and 18·8° C. (57° and 66° F.), while those drawn in winter or early spring had temperatures between 2·2° and 6·1° C. (36° and 43° F.). The extremes, therefore, were 2·2° and 18·8° C. (36° and 66° F.).

The amounts of *total nitrogen* in these varied very much, from 2·04 in No. 226 to 9·08 in No. 236, the average being 4·77; but there were too few analyses made of each class of effluent to allow of any discrimination in this respect between surface and filtration effluents. Oddly enough, the total nitrogen curve almost coincides with the "oxygen absorbed" curve, which is very curious, while the ammoniacal nitrogen and albuminoid nitrogen curves are also in agreement with both of these.

The two curves for the *organic nitrogen* are somewhat irregular as compared with the *albuminoid nitrogen* curve. There is a fair agreement between the two Kjeldahl methods for determining organic nitrogen in five analyses out of seven, neither method being however quite satisfactory.

The *chlorine* curve is very erratic.

In the case of these effluents, Mr. Scudder's incubator permanganate test was in one case *less* stringent than the incubation test as judged by smell; this is the opposite of what is usually the case in land effluents.

Three or four of these effluents were of surprisingly good quality, withstanding as they did the incubator test, and containing (for a 1st field effluent on somewhat heavy land) comparatively little organic nitrogen. The two effluents from chemically precipitated sewage (Nos. 99A and 101A) were both bad, but this may have been a coincidence. Five out of the eight effluents contained considerable amounts of nitrate. Speaking with reserve (because of the small number of analyses), the February and March effluents were better than those of June and July, although the latter were very much more free from suspended matter.

But, taking these effluents all over, one treatment on the Rugby farm soil is not sufficient for the purification of the sewage.

2nd Field (i.e. *Final*) *Effluents.* (*Diagram No.* 39.)

These were all Surface and Filtration Effluents.

Nineteen were analysed fully, and two partially, and eight of the nineteen samples were also examined in duplicate, after mercury-jointing or incubation.

Those 21 effluents, drawn in the months of February and March, June and July, varied in temperature between 0·6° and 21·1° C. (33° and 70° F.), the second highest temperature being 17·7° C. (64° F.). These are very great variations.

The following figures show some of the more important average analytical results from the examination of 16 to 19 effluents, details being given in the annexed Tables of Analysis and Curves:—

	Average.
Total Nitrogen (1·39 to 2·96)	2·31
Ammoniacal Nitrogen (0·97 to 2·81)	1·62
Albuminoid Nitrogen (0·08 to 0·39)	0·18
Nitric + Nitrous Nitrogen together (0·0 to 1·59)	0·52
"Oxygen absorbed" from permanganate at 26·7° C. (80° F.) *in* 4 *hours* (0·72 to 2·16)	1·41
Incubator Test (as judged by smell)	75% passed (20 samples tested.)

One of the effluents was colourless, but most of them had a faint yellow to brownish tinge, the colour being due to organic matter. They contained but little flocculent suspended solids (four tests were made with the centrifuge); in solution there was much lime and much sulphate. The smell, when the effluents came to be analysed, was usually earthy or a mixture of fishy and earthy, and the reaction was alkaline.

As will be seen from an examination of the analytical tables and the curves, the effluents drawn in February and March, 1901, kept very even in quality, and may be classed as fair. Those drawn in June and July, 1900 (five out of six of these being effluents from chemically precipitated sewage applied to the land) were mostly bad. These latter were hardly stronger than the others as regards total nitrogen, but the amount of oxidisable matter present, as measured by the "oxygen absorbed" test, was greater in their case.

When the effluents were analysed, the dissolved oxygen in the five summer samples from chemically precipitated sewage (Nos. 96-104) was practically *nil*. In No. 106, on the other hand (the summer sample of effluent from sewage not chemically treated), the dissolved oxygen was very high, although there was no reserve of nitrate. (These oxygens were boiled out.)

In the spring samples the dissolved oxygen was only moderate in amount (from 1 to 4 c.c.), but it did not appear to be taken up at all rapidly between the time of drawing and the time of analysis—a very good sign. (These effluents being more or less coloured, however, would tend to make the readings of the copper chloride tubes too low).

The amounts of free carbonic acid in the three samples of final effluent which were boiled out (Nos. 96, 100, and 103) were moderate (29c.c. to 35c.c.), a tolerably sure indication of a surface effluent. But there was a large quantity of combined carbonic acid in the two samples tested for this (Nos. 102 and 104), showing the presence of considerable amounts of alkaline earth bi-carbonates.

The *Ammoniacal Nitrogen* in 19 samples of effluent ranged from 0·97 to 2·81, the average being 1·62. Two-thirds of the whole nitrogen present (not a large quantity altogether) was thus in the form of ammoniacal nitrogen.

The *Albuminoid Nitrogen* in 19 samples of effluent varied from 0·08 to 0·39, the average being 0·18; while the "oxygen absorbed" in 16 samples ranged from 0·72 to 2·16, average 1·41.

The *average ratio of Albuminoid Nitrogen to "Oxygen absorbed"* from permanganate in 4 hours, after allowing for nitrite, was in sixteen effluents 1 : 8. Eight of the sixteen had ratios of 1 : 6 and 1 : 7, while the other eight varied between 1 : 8 and 1 : 10.

As regards *incubation*, 10 out of 19 effluents were condemned by Mr. Scudder's incubator permanganate test, while nine passed it*; on the other hand, five were condemned by the incubation test as judged by smell, while 15 passed it. This shows that for the Rugby 2nd Field and Final effluents Mr. Scudder's test is much the more stringent.

The *total nitrogen* in these effluents was not great, varying between 1·39 and 2·96, with an average of 2·31; it was very constant in the different effluents, taking them all over.

The *total organic nitrogen*, as determined (*a*) by Kjeldahl, *with reduction*, appears to be no greater than the albuminoid nitrogen in about half of the samples examined. Even allowing for some errors of analysis this is very curious, for, if in the main correct, it indicates that the albuminoid nitrogen is to a great extent the measure of the organic nitrogen in the Rugby final effluents—a conclusion which is opposed

* Unfortunately in the earlier samples the amount of nitrite remaining after incubation was not noted, and its oxygen equivalent could not therefore be deducted from the "oxygen absorbed" figure found. But in the cases where there is any doubt in the matter (really only in Nos. 226C. and 234C, I have given Mr. Scudder's incubation test figures the benefit of this doubt and marked the samples +.

to that arrived at from the effluents of the other farms visited. Hence one feels hesitation in accepting it, and it would be interesting to pursue the point further. (*b*) The determination of organic nitrogen by Kjeldahl, *without reduction*, was also very unequal in the results which it gave.

Almost all the Rugby effluents contained small amounts of *nitrous nitrogen* (from 0·01 to 0·08 parts). And, if we leave out of account the first set of samples drawn in 1900, and the two last ones drawn in February, 1902, the *nitric nitrogen* in the others, though never very large in amount (maximum 1·6), was always sufficient to leave a small reserve after incubation.

The *ratio of oxidized to unoxidized nitrogen* (taking the unoxidized=1) varied between 0 and 1·61, *i.e.*, in no case was it high. Out of 19 samples examined, all those with a ratio from 0·04 to 1 kept good on incubation, *as judged by smell.* (This is an indirect corroboration of the apparently abnormal results with organic nitrogen, though too much weight must not be laid upon it.) Mr. Scudder's incubation test condemned the samples with the highest ratios here, so it is obviously not applicable to these effluents. Probably a "safety limit" ratio of 0·25 : 1 would be sufficient.

Again, the ratio of *oxidized to albuminoid nitrogen* (taking the albuminoid=1) varied in the 19 effluents between 0 and 17·5. According to the incubation test as judged by smell, any ratio above that of 0·36 : 1 is sufficient. But if we reject the sample which gives this abnormal figure (No. 100), probably a safety limit ratio of 2 : 1 would suffice here—a very low ratio.

The effect of incubation upon the ammoniacal and nitric nitrogen in seven Spring samples of the Rugby 2nd field effluents is shown in the following table :—

No. of Sample - - -	225	226	226c	229	230	232	234c
Ammoniacal Nitrogen :							
(a) Before incubation -	2·10	1·08	1·64	1·65	1·44	1·17	1·05
(b) After ,, -	2·42	1·68	1·75	1·93	1·44	1·12	1·30
Nitric + Nitrous Nitrogen :							
(a) Before incubation -	0·54	0·82	0·41	0·62	0·87	0·67	0·86
(b) After ,, -	0·06	0·27	0·0	0·33	0·41	0·66	0·66

The decrease in nitric nitrogen was thus in no case very striking, though it was rather too great in No. 226.

The *chlorine* curve in these effluents was, as one would naturally expect, distinctly higher in summer than in spring, and it follows the "oxygen absorbed" curve fairly well. It will be noticed that, excepting in the summer samples, this chlorine curve is distinctly lower than that given by the hourly samples of sewage, this being evidently due to the spring rainfall.

To revert again for a moment to the somewhat uncommon system of land treatment followed at Rugby, the following effluents may be *approximately* compared with one another as showing the purification effected in this way :—

No. 99A (1st Field effluent) and No. 100 (Final effluent); in this case a good final purification has resulted.

No. 101A (1st Field) and No. 102 (Final); purification only moderate, the final effluent not being good.

No. 228 (1st Field) and No. 229 (Final); purification fair.

No. 236 (1st Field) and No. 237 (Final and General); purification excellent.

No. 238B (1st Field surface effluent) and 238C (Final and General); the former was already well purified for a 1st Field effluent, and, excepting in the matter of aeration, no further improvement is manifest in the final one.

In conclusion.—For a farm which must depend mainly upon surface irrigation over a stiff soil, the Rugby High Level farm treats a very large volume of a strong sewage—about the same volume per acre of irrigable area as Aldershot Camp although the aggregate amount of organic matter at Rugby is rather less (compare Diagrams Nos. 3 and 4). The somewhat unusual method of treatment has been already referred to. Although the results obtained from the examination of the second-field effluents at Rugby are in several respects contradictory, it will be seen that the farm is capable of producing a fair effluent of very even composition in spring; but, as regards summer, if our (comparatively few) summer samples can be taken as a general criterion of the working of the farm during that season, the area of land which is allowed for sewage then must be smaller than at other times of the year, for it was obviously insufficient. The mechanical analysis of the surface soil showed it to be more of a clay than it was originally thought to be, but the gravel "pockets" which occur in the clay subsoil no doubt to some extent assist the purification of the sewage by the filtration that takes place through them. The relative number of particles in unit weight of the ignited soil is 392, and in unit volume 456, the numbers in the Nottingham soil being taken at 100 in both cases. (Compare *Conclusions*, page 303, and also Section upon Soils, page 275.)

Percentage purification as calculated on the Albuminoid Nitrogen and the "Oxygen absorbed" in four hours.

(1.) *Albuminoid Nitrogen.*

8 chance samples of sewage (differently treated) gave (0·40 to 2·84) -	1·49
3 sets of hourly samples of screened and settled sewage gave (1·56 to 1·80) - - - - - - - - - -	1·69
19 Second Field Effluents gave (0·08 to 0·39) - - - - -	0·18
The percentage purification therefore was:—	
On chance samples - - - - - - - - -	87·9 %
On hourly samples - - - - - - - - -	89·3 %

(2.) *"Oxygen absorbed."*

8 chance samples of sewage (differently treated) gave (3·55 to 33·31) -	15·0
3 sets of hourly samples of screened and settled sewage gave (17·55 to 19·18) - - - - - - - - - -	18·44
16 Second Field Effluents gave (0·72 to 2·16) - - - - -	1·41
Percentage purification:—	
On chance samples - - - - - - - - -	90·6 %
On hourly samples - - - - - - - - -	92·4 %

Note.—Although the percentage purification works out almost the same on the chance samples of sewage as on the hourly samples, no weight can be laid upon this for the reasons already given (p.218).

Comparison of the Total Nitrogen in the Sewages and Final Effluents.

The average total nitrogen in 3 sets of hourly samples of sewage was (9·39 to 9·99) - - - - - - - - - -	9·65
The average total nitrogen in 19 Second Field Effluents was (1·39 to 2·96) - - - - - - - - - -	2·31

As already stated in the Engineering Report,* there is now not much subsoil water on the farm. So if we disregard the subsoil water on the one hand, and the loss by evaporation on the other, something like one-fourth of the total nitrogen of the sewage finds its way into the river.

Note.—The figure for the average total nitrogen in the 8 chance samples of sewage was 9·95.

* Part IV.: Engineering and Practical Report.

Water from the River Avon, with and without admixed effluent. (*Diagram No.* 40.)

Eight samples altogether were examined, three of them in duplicate after jointing or incubation. Of these, Nos. 105, 105A, and 230A were drawn above the farm effluent outfall, while Nos. 107, 108, 226B, 234A and 238A were taken below it. At the same time it will be seen from Mr. Kershaw's Notes on Samples* that the Low Level farm effluent discharges into the river about two miles above the point where sample No. 105 was drawn; in other words, every sample of river water taken at the High Level farm contains the effluent from the Low Level one. No. 107 (river water after mixing with High Level farm effluent) was drawn to correspond with No. 105, and is, in fact, the better sample of the two; while No. 108, drawn 250 yards lower down than No. 107, is to all intents and purposes the same as the latter. The remaining samples, drawn in spring, only required to be partially analysed.

The various samples were almost clear and nearly colourless (excepting that Nos. 230A and 234A were rather cloudy, from the river having been in flood when they were drawn), they contained small but appreciable amounts of suspended matter, were alkaline in reaction, and had much lime and a considerable amount of sulphate in solution. The smell was in every case clean, though tending to a fishy odour in Nos. 105 and 107.

Speaking generally, so far as non-putrescibility was concerned, no fault could be found with the river water, and, moreover, the samples maintained their aeration fairly well upon incubation. As regards the amount of nitrogenous matter present, the river was, *for a non-drinking stream*, on the whole in a fair condition, but in the summer sample, No. 105, there was a large quantity of oxidizable matter in the samples, as indicated by the "oxygen absorbed" test. Considering the normal ratio of river water to High Level farm effluent (20 : 1), this is a clear index of a large quantity of effluent entering from the Low Level farm, or of some other polluting liquid getting into the river, which has, however, sufficient volume to keep quite sweet.

Notes.—(1.) It will be observed that the curves, excepting those for the dissolved oxygen, are pretty nearly all straight lines.

(2.) The determination of organic nitrogen in these river water samples was much better carried out by the Kjeldahl process *without* reduction than by the other.

Street Washings.

No. 231 was a sample of street washings taken from a surface water drain at Rugby on March 4th, 1901, at a time when the street was very clean from heavy showers. This sample was very turbid and brown, with a large amount of gritty sediment, but comparatively pure as regards organic matter, and capable of withstanding the incubator test.

Water from Well on Sewage Farm.

Two samples of water from a well on the High Level farm (Nos. 237 and 239, drawn in February and March 1901) were analysed, the second of them in duplicate after jointing with mercury. The results are more than usually interesting, *because the land is sewaged to within* 40 *feet of the well.*

The water was clear, bright, colourless and without smell, and it was from a chemical point of view organically pure, although the large amounts of chlorine and nitric nitrogen in it show that the water itself is in all probability derived from the sewage of the farm, which has, however, undergone a most efficient oxidation and filtration. The duplicate sample, No. 239, jointed, retained its dissolved oxygen very well over a period of nine months, showing that little or no fermentable organic matter was present. At the same time it is hardly necessary to say that the above results must not be taken as pointing to the advisability of sinking a well in the middle of a sewage farm.

* Part IV.: Engineering and Practical Report.

RUGBY HIGH LEVEL SEWAGE FARM.

TABLES OF ANALYSIS.

INDEX.

PAGE.

Hourly Sewage Samples, Nos. 472, 473, 474 - - - - - - - - - - - - 227

Chemically precipitated Sewages with Effluents, Nos. 95, 96, 99 - - - - - - - - 228

" " " Nos. 99A, 100, 101. 101A, 102, 103, 104 - - 229

Sewages and Effluents, Nos. 93, 94, 97, 98, 106 - - - - - - - - - - - 230

" Nos. 224, 225, 226 - - - - - - - - - - - - 232

Effluents, Nos. 226, 226A, 226C, 228, 229 - - - - - - - - - - - - 233

Effluents, Nos. 230, 232 - - - - - - - - - - - - - - - - - 234

Sewage and Effluents, Nos. 233, 234, 234B, 234C, 234D - - - - - - - - 235

Sewage and Effluents, Nos. 235, 236, 237, 238 - - - - - - - - - - - 236

Effluents, Nos. 238B, 238C, "A" and "B" - - - - - - - - - - - - 237

River Water above and below Effluent outfall, Nos. 105, 105A, 107 - - - - - - 238

" " " Nos. 108, 226B, 230A, 234A, 238A - - - 239

Well Waters, Nos. 227, 239 - - - - - - - - - - - - - - - - 240

Street Washings, No. 231 - - - - - - - - - - - - - - - - 240

RUGBY SEWAGE FARM, 1902.

Hourly Sewage Samples drawn in Equal Quantities per Hour.

No. of Sample	472	473	474
Nature of Sample	Screened and Settled Sewage, 24 Hours' Sample.	Screened and Settled Sewage, 24 Hours' Sample.	Screened and Settled Sewage, 24 Hours' Sample.
Rainfall while samples were being drawn.	0·0″	0·0″	0·0″
Drawn	From Monday, 17th February 1902, 12 noon, to 18th February, 11 a.m.	From Tuesday, 18th February 1902, 12 noon, to 19th February, 11 a.m.	From Wednesday, 19th February 1902, 12 noon, to 20th February, 11 a.m.
Analysed	19th February 1902.	20th February 1902.	21st February 1902.
Parts per 100,000, *by weight.*			
Ammoniacal nitrogen (by distillation)	5·74	6·46	6·14
Albuminoid ,,	1·80	1·72	1·56
Nitrous ,,	0·05	0·03	0·05
Nitric ,,	0·23	0·24	0·33
Total nitrogen by Kjeldahl, *with* reduction.	9·57	9·99	9·39
Blank	(0·45 in 7·44)	(0·45 in 7·75)	(0·45 in 7·31)
"X" nitrogen	1·75	1·54	1·31
Organic nitrogen by Kjeldahl, *with* reduction.	3·55	3·26	2·87
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once.*	4·11	3·89	3·90
,, ,, ,, *after four hours.*	18·58	19·18	17·55
Chlorine	9·36	10·14	10·46
Total solids (gravimetrically)	140·6 { 71·8 volatile; 68·8 non-volatile	143·8 { 77·8 volatile; 66·0 non-volatile	137·2 { 65·6 volatile; 71·6 non-volatile
Solids in suspension ,,	50·6 { 42·2 volatile; 8·4 non-volatile	48·4 { 44·4 volatile; 4·0 non-volatile	43·0 { 32·2 volatile; 10·8 non-volatile
Solids in solution ,,	90·0 { 29·6 volatile; 60·0 non-volatile	95·4 { 33·4 volatile; 62·0 non-volatile	94·2 { 33·4 volatile; 60·8 non-volatile
Cellulose (still containing fat), by extraction with alkali and acid alone (*a*).	20·96	Not done.	12·96
Cellulose by alkali, acid and ether (*b*)	7·88	7·92	5·88
Grit { from (*a*)	5·12	——	3·84
Grit { from (*b*)	5·04	4·40	3·96
Parts per 100,000, *by volume.*			
Solids, by centrifuge	345·0 (4 minutes).	310·0 (3 minutes).	258·0 (3 minutes).
Remarks	Brown and turbid, with very considerable dark brown sediment. Slight urine smell. Alkaline. General solids up to 0·94 m.m. in length. Fibre (not much) up to 1·66 m.m. Hair (very little) up to 1·04 m.m.	Brown and turbid, with about the same amount of dark brown sediment as No. 472. Hippuric acid smell. Alkaline. Solids up to 3·64 m.m. (These were much coarser than in 472.) Fibre up to 1·87 m.m.	Turbid and brown, with very considerable dark brown sediment. Smell of cattle urine. Alkaline. Solids up to 0·57 m.m. Fibre up to 0·73 m.m. Hair up to 1·66 m.m.

RUGBY SEWAGE FARM, 1900.

Chemically Precipitated Sewages with Effluents.

No. of Sample	95	96	96	99
Nature of Sample	Screened and Chemically Precipitated Sewage from Tanks	Second Field Effluent, corresponding to Sewage No. 95.	Duplicate Sample.	Screened and Chemically Precipitated Sewage.
Drawn	Wednesday, 20th June 1900, 11.15 a.m.	Wednesday, 20th June 1900, 12.15 noon.	——	Wednesday, 27th June 1900, 12 noon.
Temperature of sample	15·0° C. (59° F.)	21·1° C. (70° F.)	——	13·3° C. (56° F.)
Temperature of air	20·6° C. (69° F.)	20·0° C. (68° F.)	——	14·4° C. (58° F.)
If jointed or incubated	——	——	Jointed, 21st June.	——
Analysed	21st June 1900.	21st June 1900.	6th July 1900.	28th June 1900.
Parts per 100,000, *by weight.*				
Ammoniacal nitrogen (a) by direct Nesslerization.	2·39	1·48	——	9·72
Ammoniacal nitrogen (b) by distillation	1·95	1·38	——	11·21
Albuminoid nitrogen	0·40	0·23	——	1·76
Nitrous ,,	None.	Trace.	——	None.
Nitric ,,	Not done.	None.	——	Not done.
Total nitrogen by Kjeldahl, *with* reduction (after nitrite correction).	2·80	1·74	——	14·20
Blank	(0·19 in 2·22)	(0·19 in 2·71)	——	(0·19 in 10·50)
Correction for nitrite	None.	None.	——	None.
"X" nitrogen	0·45	0·13	——	1·23
Organic nitrogen by Kjeldahl, *with* reduction.	0·85	0·36	——	2·99
Organic nitrogen by Kjeldahl, *without* reduction:				
(a) Taking ammonia by direct Nesslerization.	0·62	0·29	——	4·13
(b) Taking ammonia by distillation	1·06	0·39	——	2·64
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once*	0·94	0·51	0·18*	3·34
,, ,, ,, *after four hours*	3·55	1·95	——	16·13
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once*	——	0·40	——	——
,, ,, ,, *after four hours*	——	1·60	——	——
Smell after incubation	——	Sewage smell.	——	——
Chlorine	8·98	9·94	——	18·30
Gases: Parts per 1,000, *by volume.*				
Carbon dioxide (free)	——	34·59	——	——
Oxygen (boiled out)	——	1·37	——	——
Nitrogen	——	12·53*	——	——
Remarks	This sample contained a moderate amount of brown and grey flocculent deposit. Strongly alkaline. (It contained a little admixed field effluent).	This effluent came from surface treatment over rye grass. It was yellow, only slightly opalescent, and with a small amount of brown-red flocculent matter. Slowly alkaline. Clean, earthy smell. A great deal of lime and much sulphate in solution, but only a trace of iron. The colour therefore must have been due to organic matter. * Very low figure.	The flocculent matter was now nearly black, and the liquid clear, with only a slight yellow tinge. The sample was smelling distinctly, so was not further analysed. * Very low figure.	This contained much sediment for a precipitated sewage. Strongly alkaline.

RUGBY SEWAGE FARM, 1900.

Chemically Precipitated Sewages with Effluents.

99a	100	101	101a	102	103	104
First Field Effluent (off Green Oats, just cut).	Final Effluent, off Rye Grass (twice over Land).	Screened and Chemically Precipitated Sewage.	First Field Effluent, off young Oats (just cut).	Final Second Field Effluent, off Rye Grass.	Final Effluent from Precipitated Sewage, and from same Source as No. 102, but ½ acre more of Oat Land was now in use.	Final Effluent from Precipitated Sewage from same Source as No. 103.
Wednesday, 27th June 1900, 1.15 p.m.	Wednesday, 27th June 1900, 2.5 p.m.	Monday, 2nd July 1900, 10.30 a.m.	Monday, 2nd July 1900, 11.30 a.m.	Monday, 2nd July 1900, 12.25 noon.	Tuesday, 3rd July 1900, 12.15 noon.	Wednesday, 4th July 1900, 12 noon.
17·2° C. (63° F.)	15·0° C. (59° F.)	14·4° C. (58° F.)	18·9° C. (66° F.)	17·2° C. (63° F.)	17·8° C. (64° F.)	17·2° C. (63° F.)
17·2° C. (63° F.)	15·6° C. (60° F.)	18·9° C. (66° F.)	14·4° C. (58° F.)	16·1° C. (61° F.)	17·8° C. (64° F.)	17·8° C. (64° F.)
—	—	—	—	—	Jointed, 4th July.	—
28th June 1900.	29th June 1900.	3rd July 1900.	3rd July 1900.	4th July 1900.	5th July 1900.	5th July 1900.
3·70	Turbid.	9·55	3·91	3·13	2·64	2·54
3·54	1·03	9·96	4·04	2·81	2·55	2·44
0·68	0·14	1·65	0·72	0·27	0·19	0·39
None.	None.	None.	None.	None.	None.	None.
0·03	0·05	Not done.	Not done.	None.	None.	None.
4·31	1·39	12·40	5·74	2·96	2·46	2·77
(0·19 in 6·44)	(0·19 in 2·21)	(0·19 in 9·19)	(0.19 in 7·79)	(0·19 in 4·49)	(0·19 in 3·73)	(0·16 in 4·15)
None.	None.	None.	None.	None.	None.	None.
0·06	0·17	0·79	0·98	None (–0·12)	None (–0·28)	None (–0·04)
0·74	0·31	2·44	1·70	0·27	0·19	0·39
0·78	—	3·62	1·77	None (–0·12)	None (–0·05)	0·23
0·94	0·25	3·21	1·64	0·20	None (–0·14)	0·33
0·87	0·28	3·32	1·04	0·28	0·26	0·36
4·11	1·45	11·60	4·83	1·81	1·78	2·16
2·00	0·05	—	—	0·21 } six days.	0·35	0·66
4·03	1·29	—	—	1·75 } six days.	2·47	2·88
Black. Smell of ammonium sulphide.	Sweet.	—	—	Putrid.	Very putrid.	Very putrid.
—	11·60	11·80	11·78	10·98	9·86	11·66
—	29·15	—	—	151·20 *	34·71	134·81 *
—	0·07	—	—	0·05	0·12	0·23
—	14·66	—	—	14·01	13·82	13·55
This sample was very dim and only light yellow in colour. It contained hardly any (brownish) flocculent matter. Alkaline (strongly so on boiling). Smell doubtful, probably slightly putrid. Much lime and sulphate, but practically no iron in solution.	This looked a good effluent. It was very clear and pale yellow in colour, with only a little red-brown flocculent matter. Clean earthy smell. Alkaline. A great deal of lime and of sulphate, but practically no iron in solution.	This contained a moderate amount of brown and white flocculent sediment (chiefly brown). Sewage smell. Strongly alkaline.	No notes were made about this sample, but it is obviously very imperfectly purified.	This looked a good effluent. It was clear and slightly yellow in colour, with very little (light-brown) flocculent matter. Clean, fishy-earthy smell. Distinctly alkaline. A great deal of lime and much sulphate in solution, but almost no iron. * Free and combined carbon dioxide.	This looked good. Clear and amber-coloured, with only a small amount of light-brown flocculent matter. Smell doubtful. Distinctly alkaline. A great deal of lime and much sulphate, and apparently a trace of ferrous-iron in solution. **No. 103 Duplicate.** Jointed 4th July, Opened 17th July, when it was distinctly putrid.	This again looked a very good sample, clear and of a pale amber colour, with only very little brownish sediment. Fishy-earthy smell. Slightly alkaline (strongly so on warming). A great deal of lime, much sulphate, and a small amount of iron in solution. * Free and combined.

RUGBY SEWAGE FARM, 1900.

Crude Sewage, with First Field and General Effluents.

No. of Sample	93	94	97	98	106
Nature of Sample	Crude Sewage (not through tanks).	First Field Effluent (slight sewage smell when drawn).	Crude Sewage.	First Field Effluent, off Rye Grass, after 3 days' rest.	General Effluent, o two fields, *i.* Surface and tration Efflu
Drawn	Tuesday, 19th June 1900, 11 a.m.	Tuesday, 19th June 1900, 1 p.m.	Monday, 25th June 1900, 1.45 p.m.	Monday, 25th June 1900, 3.15 p.m.	Monday, 9th J 1900, 11.15 a
Temperature of sample	13·3° C. (56° F.)	15·0° C. (59° F.)	13·3° C. (56° F.)	13·9° C. (57° F.)	16·1° C. (61°
Temperature of air	20·0° C. (68° F.)	21·7° C. (71° F.)	20·6° C. (69° F.)	14·4° C. (58° F.)	20·0° C. (68°
If jointed or incubated	—	—	—	—	—
Analysed	20th June 1900	20th June 1900	26th June 1900	26th June 1900	10th July 19
Parts per 100,000, *by weight.*					
Ammoniacal nitrogen (a) by direct Nesslerization	9·99	2·96	7·41	1·38	Turbid.
Ammoniacal nitrogen (b) by distillation.	10·44	2·92	7·95	1·33	1·99
Albuminoid nitrogen	1·97	0·47	1·54	0·53	0·18
Nitrous ,,	None.	None.	None.	0·60	0·04
Nitric ,,	Not done.	0·07	Not done.	1·04	0·12
Total nitrogen by Kjeldahl, *with* reduction (after correction for nitrite).	12·76	3·65	9·93	3·20	2·03
Blank	(0·19 in 9·45)	(0·19 in 5·49)	(0·19 in 7·40)	(0·19 in 4·37)	(0·16 in 3·0
Correction for nitrite	None.	None.	None.	+ 0·32	+ 0·02
"X" nitrogen	0·35	0·19	0·44	None (?) (−0·30)	None (?) (−0
Organic nitrogen by Kjeldahl, *with* reduction.	2·32	0·66	1·98	0·53 (?)	0·18
Organic nitrogen by Kjeldahl, *without* reduction;					
(a) Taking ammonia by direct Nesslerization.	2·73	0·75	2·47	0·15	—
(b) Taking ammonia by distillation	2·28	—	1·93	0·20	0·19
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once*	4·50	1·19	3·47	1·02	0·15*
,, ,, ,, *after four hours*	15·43	4·62	15·43	Lost.	1·86
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once*	—	1·85 } Six days.	—	0·36	0·72
,, ,, ,, *after four hours*	—	5·49 } Six days.	—	1·34	1·73
Smell after incubation	—	Putrid but not blackened.	—	Putrid.	Sweet.
Chlorine	13·76	19·38	12·56	8·44	10·46
Gases: Parts per 1,000, *by volume.*					
Carbon dioxide (free)	—	—	—	61·78	160·48 †
Oxygen (boiled out)	—	—	—	0·26	7·15
Nitrogen	—	—	—	18·92	13·38
Remarks	This sewage contained a moderate amount of brown and grey deposit. Strong sewage smell. Alkaline.	This effluent was opalescent, with a small quantity of whitish particles in it. Distinctly putrid. Reaction tending to alkaline in the cold; alkaline on boiling. Much lime and much sulphate in solution, but practically no iron.	Light brown-grey deposit. Strong sewage smell.	Decidedly opalescent, with a *little* grey flocculent matter. Clean fishy - earthy smell. Neutral in the cold; alkaline on boiling. Much lime and very considerable amount of sulphate in solution, but hardly any iron.	Slightly opal cent., with small quant of brown - flocculent m ter. Eart smell. Alkali A great deal lime and a f amount of s phate in so tion; also moderate qua tity of iron.

Note.—This is really a *percolation* effluent, *i.e.*, the sewage on the surface had not reached the pick-up drain when the effluent was drawn.

* Exceptionall low figure.

† Free and co bined.

RUGBY SEWAGE FARM, 1901.

Screened and Settled Sewage with Effluents.

RUGBY SEWAGE FARM, 1901.

Screened and Settled Sewage with Effluents.

No. of Sample	224	225	225	226
Nature of Sample	Screened and Settled Sewage (dilute).	General Effluent. Does not correspond exactly to No. 224.	Small Duplicate.	First Effluent from Arable Field (surface irrigation and filtration).
Drawn	Monday, 18th February 1901, 4 p.m.	Monday, 18th February 1901, 5 p.m.	——	Wednesday, 20th February 1901, 12 noon.
Temperature of sample	5·6° C. (42° F.)	3·3° C. (38° F.)	——	2·2° C. (36° F.)
Temperature of air	5·6° C. (42° F.)	4·4° C. (40° F.)	——	3·9° C. (39° F.)
If jointed or incubated	——	——	Jointed and Incubated, 20th February.	——
Analysed	20th February 1901.	20th February 1901.	28th February 1901.	21st February 1901.
Parts per 100,000, *by weight.*				
Ammoniacal nitrogen (a) by direct Nesslerization.	5·37	2·83 (approx. ; turbid)	——	Turbid.
Ammoniacal nitrogen (b) by distillation.	5·06	2·10	2·42	1·06
Albuminoid nitrogen	0·94	0·21	0·18	0·13
Nitrous ,,	None.	0·03	None.	0·13
Nitric ,,	Not done.	0·51	0·06	0·69
Total nitrogen by Kjeldahl, *with* reduction (after correcting for nitrite up to 226 C. inclusive).	6·67	2·91	——	2·04
Blank	(0·13 in 4·97)	(0·20 in 4·44)	——	(0·13 in 3·01)
Correction for nitrite	None.	+0·02	——	+0·06
"X" nitrogen	0·67	0·06	——	0·03
Organic nitrogen by Kjeldahl, *with* reduction.	1·61	0·27	——	0·16
Organic nitrogen by Kjeldahl, *without* reduction :				
(a) Taking ammonia by direct Nesslerization.	0·76	——	——	——
(b) Taking ammonia by distillation.	1·07	None (−0·30)	——	0·24
Oxygen absorbed from permanganate at 26·7° C. (80° F.) ; *at once*	1·73	0·34	0·31	0·52
,, ,, ,, *after four hours.*	9·47	1·56	——	1·59
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.) ; *at once*	——	0·31	——	0·34
,, ,, ,, *after four hours.*	——	1·14	——	1·25
Smell after incubation	——	Strong, earthy.	No smell.	Strong, but not putrid.
Chlorine	10·40	9·54	——	8·92
Parts per 100,000, *by volume.*				
Solids by centrifuge	——	Below 10·0 (1½ minutes).	——	——
Gases : Parts per 1,000, *by volume.*				
Oxygen (by cuprous chloride) :				
(a) When sample was drawn	——	——	——	1·75
(b) ,, ,, analysed	——	None.	——	1·80
Remarks	For a sewage, a moderate amount of brown sediment. Strong sewage smell. Alkaline.	Rather turbid, brownish liquid (nearly clear when filtered), with a small amount of brown sediment. Earthy smell. Alkaline.	After incubation the liquid was brownish but clear, and with very little dark - brown sediment. No smell. Alkaline.	Opalescent, with a minute quantity of brown sediment. No smell. Alkaline.

RUGBY SEWAGE FARM, 1901.

Screened and Settled Sewage with Effluents.

226	226a	226c	226c	228	229	229
Small Duplicate.	General Effluent over Arable and Rye Grass.	General Effluent from same source as No. 226a (slight smell when drawn).	Small Duplicate.	First Effluent off Arable Field (Filtration Effluent).	Final Effluent, Arable and Rye Grass.	Small Duplicate.
—	Thursday, 21st February 1901, 11.15 a.m.	Wednesday, 22nd February 1901, 11.30 a.m.	—	Tuesday, 26th February 1901, 10.45 a.m.	Tuesday, 26th February 1901, 11.45 a.m.	—
—	2·2° C. (36° F.)	4·4° C. (40° F.)	—	4·4° C. (40° F.)	5·6° C. (42° F.)	—
—	1·7° C. (35° F.)	5·6° C. (42° F.)	—	5·6° C. (42° F.)	5·6° C. (42° F.)	—
Jointed and Incubated, 21st February.	—	—	Jointed and Incubated, 23rd February.	—	—	Jointed and Incubated, 27th February.
5th March 1901.	22nd February 1901.	23rd February 1901.	6th March 1901.	27th February 1901.	27th February 1901.	18th March 1901
—	Turbid.	—	—	Turbid.	2·39	—
1·08	1·68	1·64	1·75	2·17	1·65	1·93
0·13	0·22	0·19	0·12	0·14	0·24	0·12
None.	0·07	0·05	0·05	0·38	0·01	0·01 approx.
0·27	0·34	0·36	0·01	1·91	0·61	0·32
—	2·23	Boiled. 2·10 Not boiled 2·08	—	4·92	2·49	—
—	(0·13 in 3·33)	(0·20 in 3·23)	—	(0·20 in 7·42)	(0·20 in 3·86)	—
—	+0·03	+ 0·03	—	None.	None.	—
—	None (–0·08)	None (–0·14) None (–0·16)	—	0·32	None (–0·02)	—
—	0·22	0·19	—	0·46	0·24	—
—	—	—	—	—	—	—
—	0·69	—	—	0·61	None (–0·06)	—
0·29	0·34	0·33	0·36	1·53	0·36	None.
—	1·37	Not done.	—	4·10	1·41	0·31
—	0·43	0·33	—	0·86	0·31	—
—	0·92	0·86	—	2·60	0·88	—
Not noted. No doubt sweet.	Sweet.	Strong earthy.	Earthy.	Strongly putrid.	Sweet.	Sweet.
—	7·80	8·14	—	9·22	9·92	—
—	—	—	—	72·0	5·0	—
—	4.5	4·0	—	0·25	2·5	—
—	3·0 Two observers	2·8 3·0 Two observers	Not done. Exhausted, no doubt.	Not tried on 27th because of colour.	1·0 approx. (Two observers)	—
	Opalescent, with a slight brownish tinge. Trace of greyish sediment. Alkaline.	This sample was fairly turbid and slightly brown. Not much brown sediment. Earthy smell. Alkaline.	This incubated sample was a clear, brownish liquid, with a small amount of grey-brown sediment. Earthy smell. Alkaline.	This was a very turbid yellow liquid, with much brown sediment. On the 26th, when drawn, it was yellow and cloudy. Strong fishy smell. Alkaline.	This sample had a bluish tint and no smell when drawn. On February 27th it was noted as an almost clear, colourless liquid, with practically no sediment. Fairly strong fishy smell. Alkaline.	After incubation this was a slightly brown, clear liquid. Very little sediment. Sweet smell. Alkaline.

RUGBY SEWAGE FARM, 1901.

Effluents.

No. of Sample	230	230	232	232
Nature of Sample	Final Effluent over Arable and Rye Grass after a storm, from same source as No. 229.	Small Duplicate.	General Final Effluent over Arable and Rye Grass.	Small Duplicate.
Drawn	Wednesday, 27th February 1901, 11.40 a.m.	—	Tuesday, 5th March 1901, 12 noon.	—
Temperature of sample	5·6° C. (42° F.)	—	8·3° C. (47° F.)	—
Temperature of air	6·7° C. (44° F.)	—	11·1° C. (52° F.)	—
If jointed or incubated	—	Jointed and incubated, 28th Feb. 19th March 1901.	—	Jointed and incubated, 6th March. 18th March 1901.
Analysed	1st March 1901.		6th March 1901.	
Parts per 100,000, *by weight.*				
Ammoniacal nitrogen (a) by direct Nesslerization.	2·0 { approximate (very turbid) }	—	Turbid.	—
Ammoniacal nitrogen (b) by distillation.	1·44	1·44	1·17	1·12
Albuminoid nitrogen	0·20	0·09	0·11	0·09
Nitrous ,,	0·05	None.	0·08	0·07
Nitric ,,	0·82	0·41	0·59	0·59
Total nitrogen by Kjeldahl, *with* reduction (no correction for nitrite).	Distilled 11th March 2·39 Distilled 25th March 2·44	—	2·07	—
Blank	(0·21 in 3·71 and in 3·79)	—	(0·13 in 3·14)	—
"X" nitrogen	None (—0·12) None (—0·07)	—	0·12	—
Organic nitrogen by Kjeldahl, *with* reduction.	0·20 (?)	—	0·23	—
Organic nitrogen by Kjeldahl, *without* reduction:				
(a) Taking ammonia by direct Nesslerization.	None.	—	—	—
(b) Taking ammonia by distillation.	None (—0·40)	—	0·45	—
Oxygen absorbed from permanganate at 26·7° C (80° F.); *at once.*	0·34	0·24	0·16	0·31
,, ,, ,, *after four hours.*	1·47	—	1·05	—
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once*	0·45	—	0·24	—
,, ,, ,, *after four hours.*	1·25	—	1·06	—
Smell after incubation	Sweet.	Faint earthy.	Sweet.	Earthy.
Chlorine	8·18	—	6·52	—
Parts per 100,000, *by volume.*				
Solids by centrifuge	10·0	—	—	—
Gases · Parts per 1,000, *by volume.*				
Oxygen (by cuprous chloride):				
(a) When drawn	—	—	3·5	—
(b) ,, analysed	{ 0·4 0·5 } Two observers	—	2·8 { Two observers }	—
Remarks	This was a slightly turbid brownish liquid, with not very much brown sediment. Rather fishy smell. Alkaline.	Brown after incubation, with a small amount of aggregated brown suspended matter. Faint earthy smell.	Rather cloudy when drawn. On 6th March brownish, with a very small amount of brown sediment. Earthy smell. Alkaline.	After incubation this was clear, with a brown tinge. The suspended matter had aggregated to one small dark-brown piece, about one-eighth inch in diameter. Earthy smell.

RUGBY SEWAGE FARM, 1901.

Effluents, with one Sample of Crude Sewage.

233	234	234b	234c	234c	234d
CRUDE SEWAGE before passing through Tanks (oily film on surface; dilute from rain).	GENERAL EFFLUENT over Arable and Rye Grass, corresponding to Sewage No. 233.	GENERAL EFFLUENT over Arable and Rye Grass.	GENERAL EFFLUENT over Arable and Rye Grass, from same source as No. 234.	SMALL DUPLICATE.	GENERAL EFFLUENT over Arable and Rye Grass.
Wednesday, 6th March 1901, 11.15 a.m.	Wednesday, 6th March 1901, 12·45 Noon.	Thursday, 7th March 1901, 10.45 a.m.	Friday, 8th March 1901, 11.5 a.m.	—	Saturday, 9th March 1901, 11.50 a.m.
8·3° C. (47° F.)	5·6° C. (42° F.)	4·4° C. (40° F.)	5·6° C. (42° F.)	—	5·0° C. (41° F.)
5·0° C. (41° F.)	5·0° C. (41° F.)	5·0° C. (41° F.)	5·0° C. (41° F.)	—	5·0° C. (41 F.°)
—	—	—	—	Jointed and incubated, 9th March.	—
7th March 1901.	7th March 1901.	8th March 1901.	9th March 1901.	22nd March 1901.	11th March 1901.
3·85	Turbid.	Turbid.	Turbid.	—	Turbid
3·32	0·98	0·97	0·99	1·05	1·30
0·84	0·11	0·08	0·11	0·06	0·09
0·08	0·03	0·04	0·05	0·03 approx.	0·01
Not done.	1·56	1·36	0·84	0·83	0·65
5·92	Distilled 20th March 2·57 Distilled 30th March 2·59	2·75	2·12	—	2·08
(0·13 in 4·43)	(0·20 in 3·99 and 4·00)	(0·13 in 4·12)	(0·20 in 3·31)	—	(0·13 in 3·15)
1·68	None (–0·11) None (–0·09)	0·30	0·13	—	0·03
2·52	0·11 (?)	0·38	0·24	—	0·12
1·57	—	—	—	—	—
2·10	—	0·33	—	—	0·17
2·36	0·16	0·15	0·20	0·27	0·13
15·06	0·84	0·72	—	—	0·85
— —	0·28 0·92	0·31 0·96	0·19 1·08	— —	0·32 0·92 } 7 days.
—	Strong but sweet.	Sweet, earthy; 0·03 to 0·04 nitrite nitrogen.	Sweet.	Sweet.	Sweet; 0·01 to 0·02 nitrite nitrogen.
4·86	7·00	6·80	5·80	—	6·84
—	Mere trace.	—	—	—	—
— —	— 3·5, 3·7 Two observers	— 3·75, 3·70 Three observers	— 3·2, 3·0 Two observers	— Not done.	— 3·25, 3·4 Two observers.
Reddish brown, with a good many tea leaves (of which the large pieces were kept out of the analysis). Soapy—not sewage—smell. Alkaline. *Note.*—Nitrate should have been tested for in this sewage.	This had a faint yellow colour when drawn, and caused brownish-black swirls in the river just on leaving the effluent outfall. On 7th March it was brownish and slightly turbid, but with no sediment and only a small amount of brown matter in suspension. Faint fishy smell.	This was slightly brownish and opalescent, with only a very small amount of brown sediment. Earthy smell. A very large amount of lime and also much sulphate in solution, but no iron, or practically none.	Brownish and rather turbid liquid, with a very small amount of dark brown sediment. Earthy smell. Alkaline.	Clear and colourless, with one small aggregate of light brown sediment. Sweet smell. Alkaline.	When running into the brook this caused the same discoloration of the water as No. 234. It was clear, with a slight brown tinge, and a minute quantity of brownish sediment. Earthy smell. A large amount of lime and a considerable or large amount of sulphate in solution. No iron, or practically none.

RUGBY SEWAGE FARM, 1901–2.

Effluents with one Crude Sewage.

No. of Sample	235	236	237	238
Nature of Sample	Crude Sewage (not Settled).	First Effluent off Arable and Rye, *i.e.*, Surface Effluent over one Field.	Final General Effluent (twice over Land).	Final General Effluent (twice over Land).
Drawn	Monday 11th Mar. 1901, 11.10 a.m.	Monday 11th Mar. 1901, 12.30 noon.	Monday 11th March 1901, 1.15 p.m.	Wednesday, 13th March 1901, 11.20 a.m.
Temperature of sample	7·8° C. (46° F.)	5·6° C. (42° F.)	6·1° C. (43° F.)	6·7° C. (44° F.)
Temperature of air	5·6° C. (42° F.)	6·7° C. (44° F.)	7·8° C. (46° F.)	3·3° C. (38° F.)
If jointed or incubated	——	——	——	——
Analysed	12th March 1901.	12th March 1901.	13th Mar. 1901.	14th March 1901.
Parts per 100,000, *by weight.*				
Ammoniacal nitrogen (a) by direct Nesslerization.	9·55*	Turbid.	Turbid.	Turbid.
Ammoniacal nitrogen (b) by distillation.	9·37	6·82	1·57	1·57
Albuminoid nitrogen	2·84	1·07	0·13	0·15
Nitrous "	None.	0·24	0·01	0·03
Nitric "	Not done.	0·50	0·37	0·48
Total nitrogen by Kjeldahl, *with* reduction (no correction for nitrite).	14·94	9·08	2·20	Distilled 26th March, 2·22; 3rd April, 2·17*
Blank	(0·13 in 10·97)	(0·20 in 6·86)	(0·13 in 3·33)	(0·20 in 3·46)
"X" nitrogen	2·73	0·45	0·12	None (− 0·01)
Organic nitrogen by Kjeldahl, *with* reduction.	5·57	1·52	0·25	0·15
Organic nitrogen by Kjeldahl, *without* reduction:				
(a) Taking ammonia by direct Nesslerization.	3·74	——	——	——
(b) Taking ammonia by distillation.	3·92	——	0·35	None (− 0·09)
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once.*	6·51	2·43	0·30	0·41
" " " *after four hours.*	33·31	9·70	Lost.	1·08
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once.*	——	5·31	0·24	0·22
" " " *after four hours.*	——	8·95	0·86	0·78
Smell after incubation	——	Strongly putrid.	Sweet; 0·02 to 0·03 parts nitrite nitrogen.	Sweet.
Chlorine	12·72	10·40	7·08	7·44
Parts per 100,000, *by volume.*				
Solids by centrifuge	——	130·0	——	No sediment.
Gases: Parts per 1,000, *by volume.*				
Oxygen (by cuprous chloride):				
(a) When sample was drawn	——	None.	4·25	4·0
(b) " " analysed	——	——	3·7 (Two observers)	3·4, 3·5, 3·6 (Three observers)
Remarks	Very considerable brown sediment. Sewage and paraffine smell. Alkaline. * The equivalent of 0·125 c.c. was taken.	Very turbid yellow liquid, with a considerable though not very large amount of sediment (partly fibres and roots). Very strong fishy (not sewage) smell. Alkaline. There were large quantities of lime and sulphate in solution, and, I think, a little iron. *Note.*—When this was drawn on 11th March, it had a strong sewage smell.	When drawn, this sample was clear and without smell. On 13th March it was clear, with a brownish tinge, and a minute quantity of brown sediment. Slight earthy smell.	Liquid slightly brown and slightly turbid. No sediment. Fishy smell. Alkaline. * Probably a trifle low. I think there must have been some "X" nitrogen here.

RUGBY SEWAGE FARM, 1901–2.

Effluents.

238b First Field Effluent, *i.e.*, Surface Effluent.	238c Final General Effluent, twice over Land, corresponding to No. 238b.	238c Small Duplicate.	"A" Surface and Filtration Effluent.	"B" Surface and Filtration Effluent.
Thursday, 14th March 1901, 11.5 a.m.	Thursday 14th March 1901, 11.45 a.m.	—	Monday 17th Feb. 1902, 12.30 noon.	Wednesday 19th Feb. 1902, 11 a.m.
6·1° C. (43° F.)	5·6° C. (42° F.)	—	0·6° C. (33° F.)	0·6° C. (33° F.)
5·0° C. (41° F.)	5·0° C. (41° F.)	—	5·6° C. (42° F.)	3·3° C. (38° F.)
—	—	Jointed and Incubated, 15th March. 22nd March 1901.	—	—
15th March 1901.	15th March 1901.		18th February 1902.	Opened 24th February 1902.
Turbid.	Turbid.	—	—	—
1·04	1·39	1·54	—	—
0·12	0·14	0·09	—	—
0·04	0·03	0·05	0·01	—
0·81	0·73	0·69	0·15	—
2·21	2·33	—	—	—
(0·20 in 3·44)	(0·16 in 3·54)	—	—	—
0·21	0·04	—	—	—
0·33	0·18	—	—	—
—	—	—	—	—
None (– 0·35)	0·19	—	—	—
0·41	0·28	0·35	—	—
1·19	1·13	—	—	—
0·04	0·30	—	—	—
0·57	1·27	—	—	—
Strong, but not putrid.	Strong, but sweet; 0·01 or 0·015 nitrite nitrogen.	Sweet.	—	—
7·40	7·50	—	—	—
Too little sediment to centrifuge.	—	—	—	—
—	4·0	—	—	—
None.	3·2	—	Mere trace. Distinctly less than 1·0 c.c.	—
This sample was cloudy and had a sewage smell when drawn. On 15th March it was a fairly turbid brown liquid, with only a small amount of greyish-brown sediment and two small pieces of weed of some kind. Fishy smell. Alkaline.	Clear and odourless when drawn. On 15th March it was opalescent, with a slight brown tinge and a minute quantity of brown sediment. No smell. Alkaline.	After incubation this liquid had a very slight brown tinge. Only two small pieces of aggregated brown sediment. Sweet smell.	This effluent was cloudy when drawn, and on 18th February contained a small but appreciable amount of flocculent matter.	When opened, this was smelling. Not analysed

RUGBY SEWAGE FARM, 1900–1901.

River Water alone and admixed with Effluent.

No. of Sample	105	105	105a	107
Nature of Sample	River Water above Effluent Outfall. River very low but Bed clear.	Duplicate Sample.	River Water above Effluent Outfall. Drawn by Farm Manager on 20th July presumably. This Sample was meant to replace No. 105 Duplicate.	River Water after Mixing with Effluent. Drawn 80 yards below Junction.
Drawn	Monday, 9th July 1900, 11 a.m.	—	—	9th July 1900, 11.30 a.m.
Temperature of sample	16·1° C. (61° F.)	—	—	16·1° C. (61° F.)
Temperature of air	17·8° C. (64° F.)	—	—	17·2° C. (63° F.)
If jointed or incubated	—	Jointed, 10th July	Jointed, 21st July	—
Analysed	11th July 1900.	17th July 1900	30th July 1900	11th July 1900
Parts per 100,000, *by weight.*				
Ammoniacal nitrogen (a) by direct Nesslerization.	Turbid	Turbid.	—	Turbid.
Ammoniacal nitrogen (b) by distillation.	0·04	0·01	—	0·09
Albuminoid nitrogen	0·04	0·04	—	0·05
Nitrous ,,	0·03	None.	0·21	0·03
Nitric ,,	0·28	0·27		0·23
Total nitrogen by Kjeldahl, *with* reduction (after nitrite correction).	0·36	0·29	—	0·33
Blank	(0·19 in 0·68)	(0·16 in 0·58)	—	(0·16 in 0·61)
Correction for nitrite	+0·02	None.	—	+0·02
"X" nitrogen	None (−0·03)	None (−0·03)	—	None (−0·07)
Organic nitrogen by Kjeldahl, *with* reduction.	0·04	0·04	—	0·05
Organic nitrogen by Kjeldahl, *without* reduction:				
(a) Taking ammonia by direct Nesslerization.	—	—	—	—
(b) Taking ammonia by distillation.	0·11	0·09	—	0·12
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once.*	0·66	0·32	—	0·34
,, ,, ,, *after four hours.*	1·46	1·08	—	0·60
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once*	0·35	0·09	—	0·22
,, ,, ,, *after four hours.*	1·04	0·53	—	0·52
Smell after incubation	Sweet.	Sweet.	—	Sweet.
Chlorine	2·42	—	—	2·90
Parts per 100,000, *by volume.*				
Solids by centrifuge	—	—	—	—
Gases; Parts per 1,000, *by volume.*				
Carbon dioxide (free)	95·48*	Gases unfortunately lost.	21·33	28·30
Oxygen (boiled out)	4·04	—	2·61	5·64
Oxygen (by cuprous chloride):				
(a) When drawn	—	—	—	—
(b) ,, analysed	—	—	—	—
Nitrogen	14·64	—	*11·59	14·20
Remarks	Almost clear and colourless, but with an appreciable quantity of rather large grey-black particles. Fishy-earthy smell. Strongly alkaline. A great deal of lime in solution and a fair amount of sulphate, but no iron, or practically none. This bottle had a bad stopper.	A small bubble of gas at top of bottle, some water, as usual, having pushed through the mercury. This last week was very hot. Water clear, but for some rather large black and brown particles. Fishy-earthy smell. Alkaline.	Since 21st July weather had been for most part very hot. A moderate sized bubble at top of bottle. Water clear and colourless, but for a few brownish and black specks. Smell quite sweet. Distinctly alkaline. Much lime. Considerable sulphate. Practically no iron.	Clear and bright, with but very little brown matter (in smallish particles), less than in the brook water alone. Fishy-earthy smell. Distinctly alkaline. A great deal of lime, and a considerable amount of sulphate in solution. *Note.*—The stopper of this bottle might have been better.
	* Free and combined.		* Exceedingly low figure.	

RUGBY SEWAGE FARM, 1900–1901.

River Water alone and admixed with Effluent.

108	226b	226b	230a	230a	234a	238a
River Water after Mixing with Effluent. Drawn 250 yards lower down than No. 107.	Small Sample of River Water after Mixing with Effluent. Drawn 200 yards below Outfall.	Small Duplicate.	River Water above Effluent Outfall.	Small Duplicate.	River Water. Drawn 80 yards below Effluent Outfall.	River Water containing Effluent. Drawn 10 yards below Effluent Outfall.
th July 1900, 12 noon.	Thursday, 21st Feb. 1901, 11.30 a.m.	—	Friday, 1st March 1901, 11 a.m.	—	Wednesday, 6th Mar. 1901, 12.50 noon.	Wednesday, 13th Mar. 1901, 11.30 a.m.
16·1° C. (61° F.)	2·2° C. (36° F.)	—	5·6° C. (42° F.)	—	4·4° C. (40° F.)	6·1° C. (43° F.)
17·2° C. (63° F.)	1·7 C. (35° F.)	—	8·9° C. (48° F.)	—	5·0° C. (40° F.)	3·3° C. (38° F.)
—	—	Jointed and incubated 22nd Feb.	—	Jointed and incubated; presumably on 2nd Mar.	Jointed and incubated, 7th Mar.	Jointed and incubated, 14th Mar.
12th July 1900.	22nd Feb. 1901.	11th Mar. 1901.	2nd March 1901.	9th March 1901.	21st Mar. 1901.	25th March 1901.
Turbid.	—	—	Turbid.	—	—	—
0·07	0·07	—	0·02	—	0·03	—
0·05	0·04	—	0·03	—	0·03	—
0·04	0·32	None.	Mere trace.	*0·24	None.	None.
0·23		0·31	0·23		0·40	0·37
0·37	—	—	0·35	—	—	—
(0·19 in 0·69)	—	—	(0·20 in 0·71)	—	—	—
+0·02	—	—	None.	—	—	—
None (−0·02)	—	—	0·07	—	—	—
0·05	—	—	0·10	—	—	—
Turbid.	—	—	—	—	—	—
—	—	—	—	—	—	—
0·33	0·04	—	0·06	—	0·07	Too small to estimate.
0·63	—	—	Not done.	—	—	—
0·26	—	—	None.	—	—	—
0·77	—	—	0·30	—	—	—
Sweet.	—	—	Sweet.	—	—	—
2·74	—	—	2·52	—	—	—
—	—	—	Not enough sediment.	—	—	—
*96·02	—	—	—	—	—	—
5·01	—	—	—	—	—	—
—	8·0	—	6·5	—	—	6·25
—	—	*3·80 { Two observers.	6·7 { Two observers.	3·75	—	1·85
13·73	—	—	—	—	—	—
Clear, and with only a slightly browner tint than tap water. Comparatively few specks of red brown flocculent matter. Clean smell. Alkaline. Much lime and considerable sulphate.	Clear, but slightly brown, with a little light brown flocculent sediment. No smell. The river was high at the time.	—	When drawn, this was rather cloudy from flood water. On 2nd March it was slightly turbid and slightly brownish, with a a little brown sediment. No smell. Alkaline. A large amount of lime in solution, but no sulphate, or practically none, and no iron.	This sample has retained its oxygen fairly.	The river was very high and the water a cloudy blue when this sample was drawn. After incubation the sample was practically colourless, with a considerable amount of dark brown sediment. No smell. Alkaline.	River still fairly high when this was drawn.
* Free and combined.		*A very small bubble of air in tube.		*The nitrous nitrogen in this was approximately 0·03.		

RUGBY SEWAGE FARM, 1901.

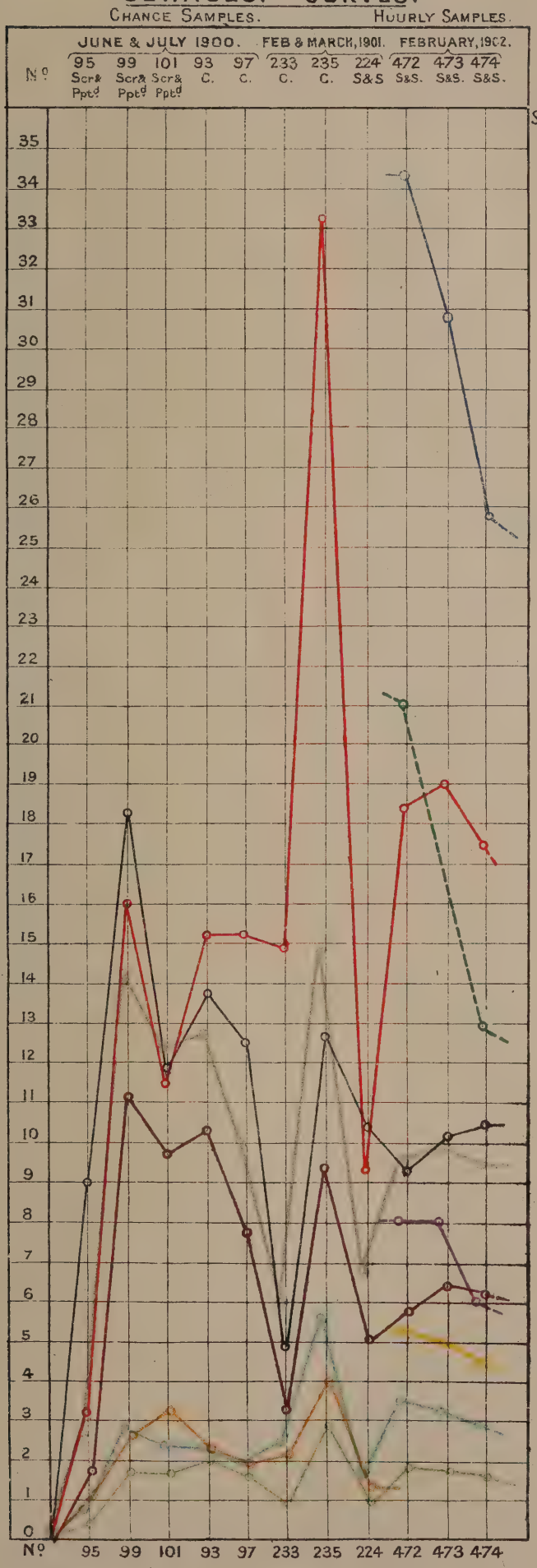
Well Waters. Street Washings.

No. of Sample	227	239	239	231	231
Nature of Sample	Water from Well on Farm; to represent Subsoil Water. Well 20 feet deep, with 10 feet of Water.	Well Water from Farm, Same Source as 227.	Large Duplicate.	Street Washings taken from a Surface Water Drain; Street very clean from heavy showers.	Small Duplicat
Drawn	Monday, 25th February 1901, 12 noon.	Thursday, 14th March 1901, 10 a.m.	——	Monday, 4th March 1901, 10 a.m.	——
Temperature of sample	7·8° C. (46° F.)	7·8° C. (46° F.)	——	3·9° C. (39° F.)	——
Temperature of air	10·0° C. (56° F.)	4·4° C. (40° F.)	——	6·1° C. (43° F.)	——
If jointed or incubated	——	——	Jointed, 15th March 1901, and kept for nine months.	——	Jointed and i ted, 5th Marc
Analysed	26th February 1901	15th March 1901.	16th December 1901	4th March 1901	19th March 1
Parts per 100,000, *by weight.*					
Ammoniacal nitrogen (a) by direct Nesslerization.	To small to estimate.	Too small.	——	——	——
Ammoniacal nitrogen (b) by distillation	0·0008	0.0004	0·0003	0·09	0·15
Albuminoid nitrogen	0·012	0·012	0·012	0·10	0·10
Nitrous "	None.	None.	None.	Heavy trace, say 0·01	0·02
Nitric "	4·53 {This must be too low.}	4·96 {Probably too low.}	5·35	0·05	
Total nitrogen by Kjeldahl, *with* reduction (no correction for nitrite).	5·03	5·34	5·59	0·38	——
Blank	(0.13 in 7·43)	(0·16 in 7·91)	(0·26 in 4·34)	(0·20 in 0·76)	——
"X" nitrogen	?	?	?	0·13	——
Organic nitrogen by Kjeldahl, *with* reduction.	?	?	?	0·23	——
Organic nitrogen by Kjeldahl, *without* reduction:					
(a) Taking ammonia by direct Nesslerization.	——	——	——	——	——
(b) Taking ammonia by distillation	0·006	0·042	——	0·24	——
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once.*	Too small to estimate.	Too small.	0·06	0·66	0·55
" " " *after four hours*	0·13	0·13	0·23	1·83	——
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once*	0·04 {Seven days.}	0·07	0·06	0·54	——
" " " *after four hours*	0·09	0·14	0·12	2·81	——
Smell after incubation	No smell.	Sweet; no nitrite.	No smell; no nitrite.	Sweet.	Rather soap
Chlorine	9·90	10·16	——	None, or merest trace.	——
Parts per 100,000, *by volume.*					
Solids by centrifuge	——	——	——	91·0	——
Gases: Parts per 1,000, *by volume.*					
Oxygen (by cuprous chloride):					
(a) When sample was drawn	(?) 4·25	3·0	——	——	——
(b) " " " analysed	{* 3·2, 3·0} Two observers.	{3·25, 3·35} Two observers.	{3·3, 3·6, 3·0} Three observers.	Not done because of sediment.	——
Remarks	This well was sunk into the lias clay. The sample was drawn from the pump after three minutes pumping. It was clear, bright and colorless, with no smell, and contained only two or three minute brown par particles. *A small bottleful, transferred and incubated till 9th March, gave 2·8 c.c., oxygen.	Clear, bright, and colourless, with a few small rather flocculent whitish particles. Slight earthy smell. Alkaline. An excessive amount of lime, and a large amount of sulphate in solution.	Clear, bright, and colourless, with very minute brown sediment. No smell. Alkaline. This water appears to have undergone little or no change in these nine months; doubtless, however, the above reading for dissolved oxygen is rather high, from the standard tubes having weakened.	There was not much vehicular traffic on this street. The sample would include water from the front roofs of houses. This sample was very turbid and brown (brown and turbid even when filtered), with a large amount of gritty sediment. No smell.	Very brown turbid, with large amoun grit. Rather s smell after bation. The above a ses show how street wash *may* be, chemic

Diagram No. 37.

RUGBY SEWAGE FARM.

SEWAGES. CURVES.



Nature of Sewage

C = *Crude*
Scr&Pted = *Screened and Precipitated.*
S&S = *Screened and Settled.*

REFERENCE

Parts per 100.000. by Weight.

Albuminoid Nitrogen ..... *Shewn thus*

Organic Nitrogen by Kjeldahl, with Reduction .....

Organic Nitrogen by Kjeldahl, without Reduction .....

Ammoniacal Nitrogen .....

Total Nitrogen by Kjeldahl, with Reduction .....

"Oxygen absorbed" from Permanganate at 26·7°C (80°F.) in four hours .....

Chlorine (Combined) .....

Solids in Suspension (Gravimetrically) (Scale divided by 10) .....

Cellulose .....

Cellulose (still containing fat) .....

Parts per 100.000. by Volume.

Solids in Suspension (by Centrifuge) (Scale divided by 10)

Note

Figures in the Vertical line represent "Parts per 100.000."

Figures in the Horizontal line represent the numbers of the Samples analysed.

A dotted line is used when there is a break in the curve.

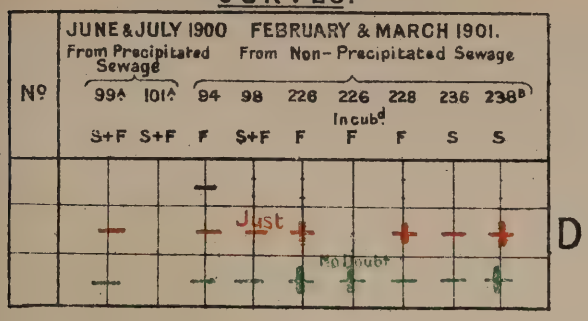
3332.8.02.

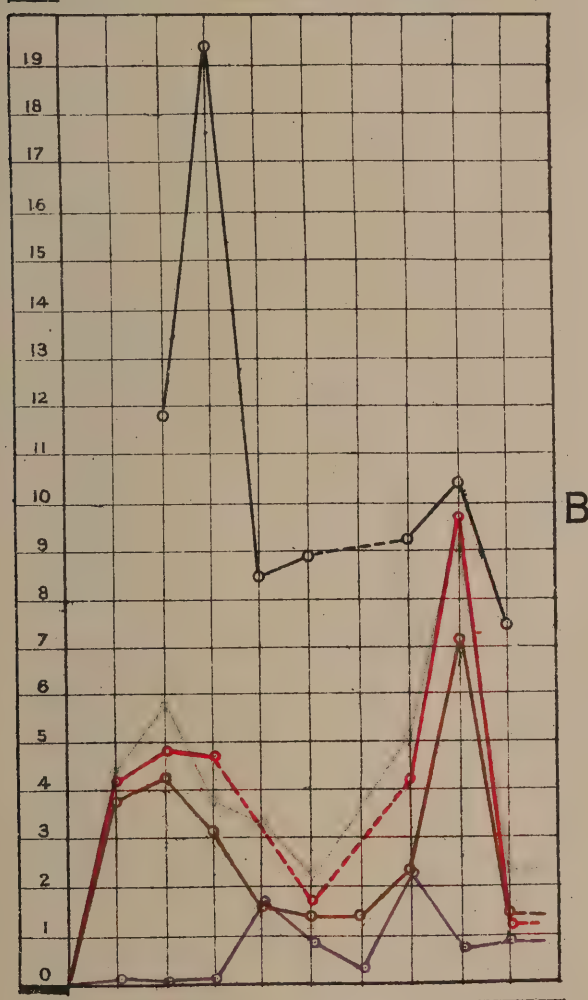
Weller & Graham Ltd Litho, London

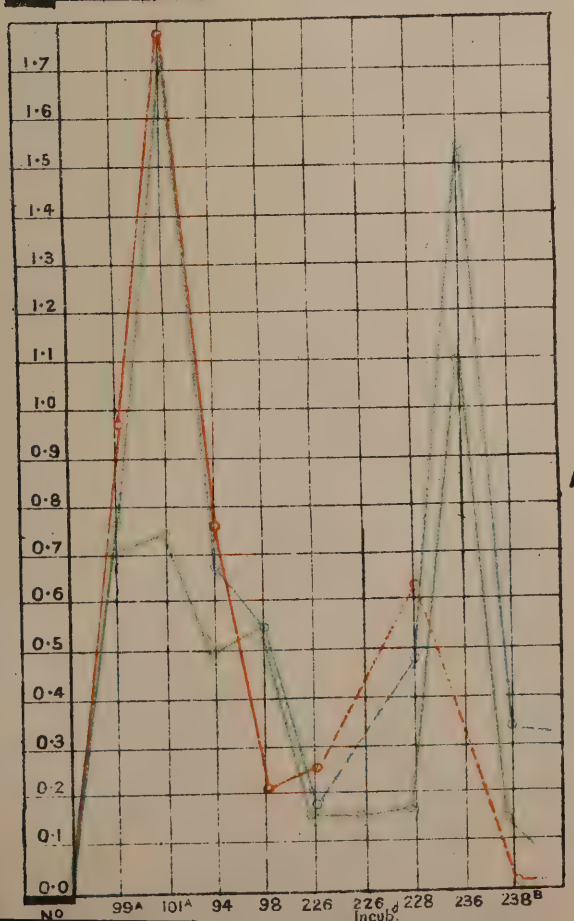
RUGBY SEWAGE FARM.

1ST FIELD EFFLUENTS. CURVES.

Diagram No. 38







Note

S = Surface Effluent
F = Filtration " "

"Incubated" Indicates a sample jointed and allowed to stand for five days or longer at a temperature of 26.7°C (80°F.)

REFERENCE

Smell of Samples when drawn Shewn thus + or —

Scudder's Incubation Test ..... + —

Incubation test as judged by Smell + —

Parts per 1,000, by Volume (C.C. per Litre)

Dissolved Oxygen when sample was drawn Shewn thus

Dissolved Oxygen when sample was analysed

Parts per 100,000, by Weight.

Ammoniacal Nitrogen ..... Shewn thus

Total Nitrogen by Kjeldahl. with Reduction. .....

Nitric + Nitrous Nitrogen (together) .....

"Oxygen absorbed" from Permanganate at 26·7°C (80°F.) in four hours. .....

Chlorine (Combined) .....

Albuminoid Nitrogen ..... Shewn thus

Organic Nitrogen by Kjeldahl, with Reduction. .....

Organic Nitrogen by Kjeldahl, without Reduction. .....

Note

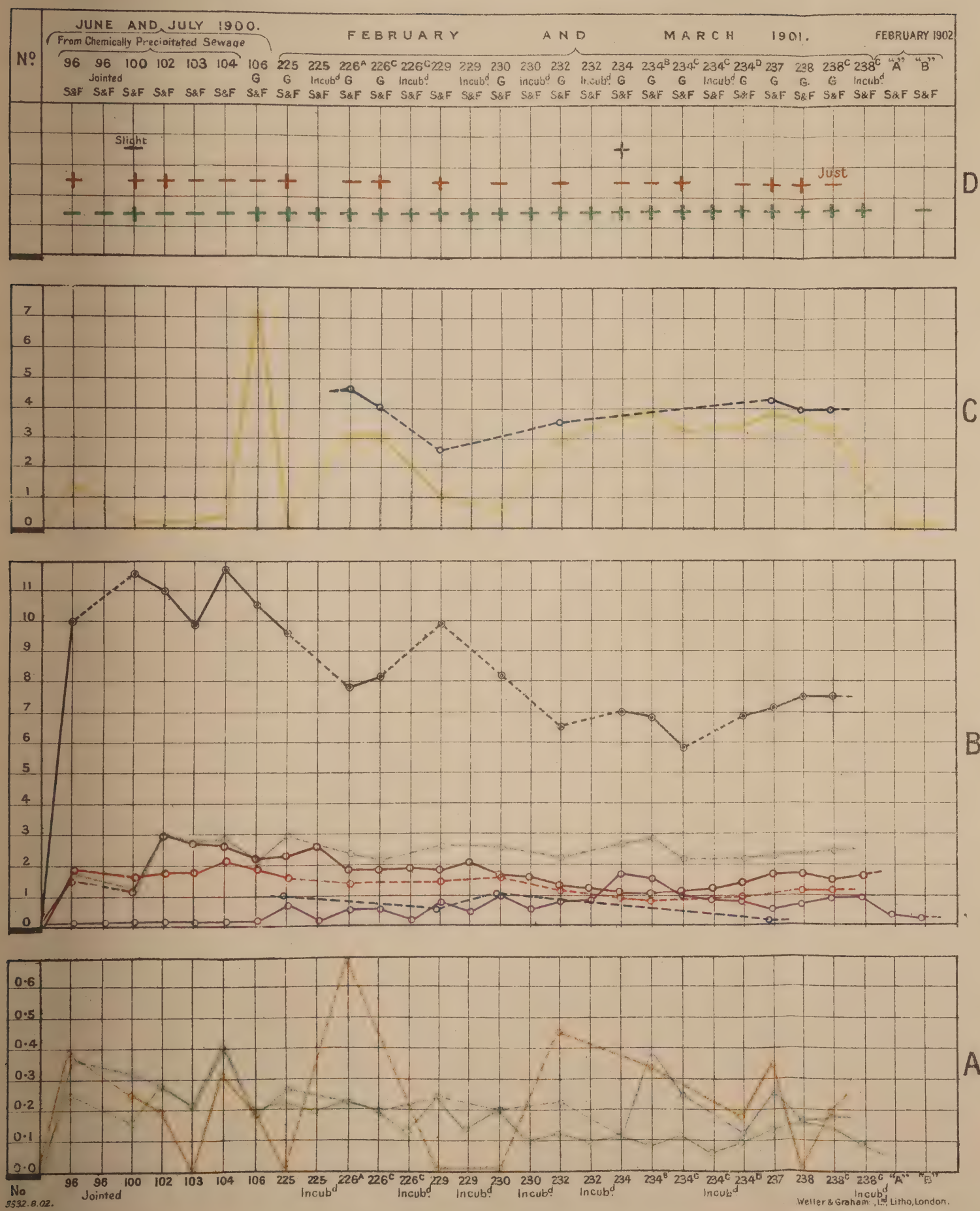
Figures in the Vertical line represent "Parts per 100,000."

Figures in the Horizontal line represent the numbers of the Samples analysed.

A dotted line is used when there is a break in the curve.

Diagram No 39.

RUGBY SEWAGE FARM. 2ND FIELD EFFLUENTS. CURVES.



Note.
S = Surface Effluent
F = Filtration " "
G = General " "
"Jointed" Indicates a sample jointed and allowed to stand at laboratory temperature
"Incubated" Indicates a sample jointed and allowed to stand for five days or longer at a temperature of 26.7°C (80°F.).

REFERENCE

Smell of Samples when drawn Shewn thus + or −

Scudder's Incubation Test ..... + −

Incubation test as judged by Smell + −

Parts per 1000, by Volume (C.C. per Litre)

Dissolved Oxygen when sample was drawn Shewn thus ——

Dissolved Oxygen when sample was analysed

Parts per 100.000, by Weight.

Ammoniacal Nitrogen..... Shewn thus

Total Nitrogen by Kjeldahl, with Reduction.....

Nitric + Nitrous Nitrogen (together)

"Oxygen absorbed" from Permanganate at 26·7°C (80°F.) in four hours.....

Chlorine (Combined).....

Parts per 100.000, by Volume.

Solids in suspension (by Centrifuge) (Scale divided by 10)

Parts per 100.000, by Weight.

Albuminoid Nitrogen..... Shewn thus

Organic Nitrogen by Kjeldahl, with Reduction.....

Organic Nitrogen by Kjeldahl, without Reduction.....

Note
Figures in the Vertical line represent "Parts per 100.000."

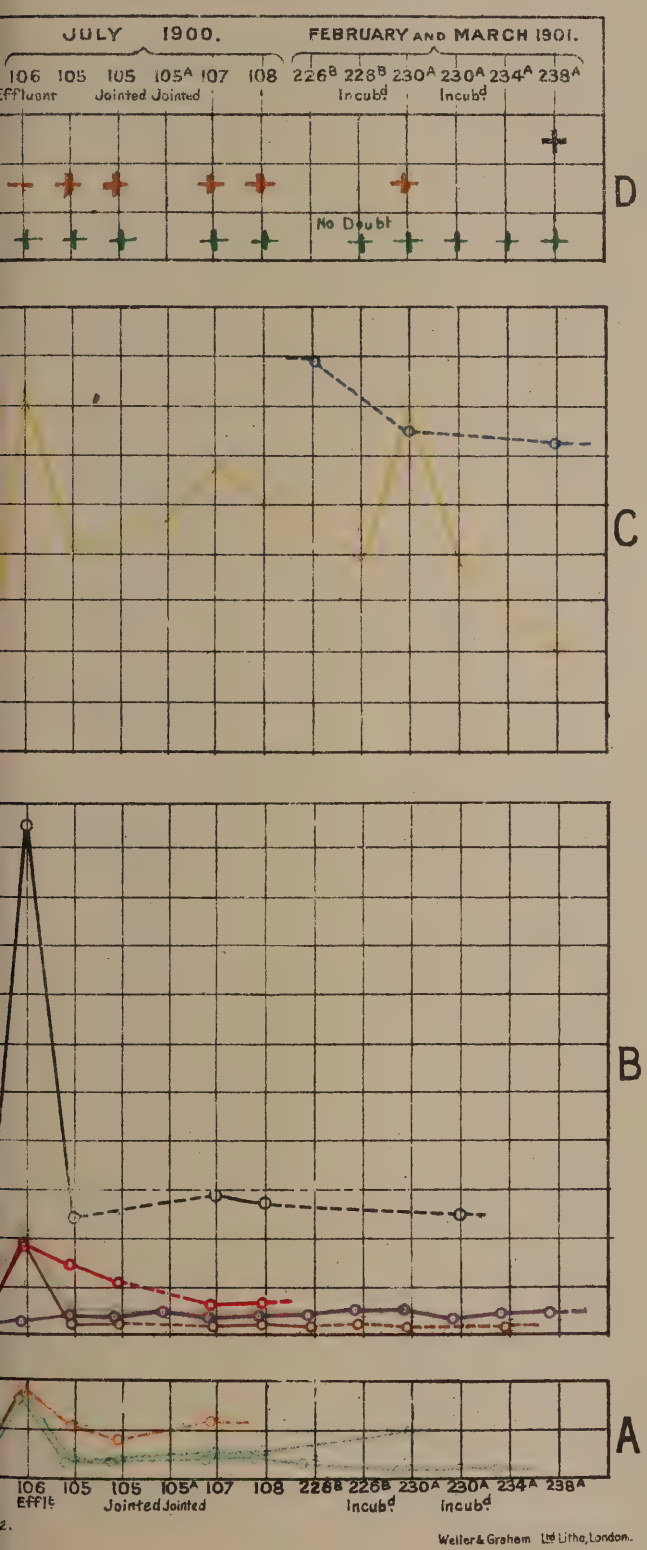
Figures in the Horizontal line represent the numbers of the Samples analysed.

A dotted line is used when there is a break in the curve.

No 9532.8.02.

Diagram No. 40.

RUGBY SEWAGE FARM.
RIVER WATER. CURVES.



Note

"Jointed" Indicates a sample jointed and allowed to stand at laboratory temperature.
"Incubated" Indicates a sample jointed and allowed to stand for five days or longer at a temperature of 26.7°C (80°F.)

REFERENCE

Smell of Samples when drawn Shewn thus + or –

Scudder's Incubation Test ..... + –

Incubation test as judged by Smell + –

Parts per 1.000, by Volume (C.C. per Litre)

Dissolved Oxygen when sample was drawn Shewn thus

Dissolved Oxygen when sample was analysed

Parts per 100.000, by Weight.

Ammoniacal Nitrogen ..... Shewn thus

Total Nitrogen by Kjeldahl, with Reduction .....

Nitric + Nitrous Nitrogen (together) ....

"Oxygen absorbed" from Permanganate at 26·7°C (80°F.) in four hours .....

Chlorine (Combined) .....

Albuminoid Nitrogen ..... Shewn thus

Organic Nitrogen by Kjeldahl, with Reduction .....

Organic Nitrogen by Kjeldahl, without Reduction .....

Note

Figures in the Vertical line represent "Parts per 100.000."

Figures in the Horizontal line represent the numbers of the Samples analysed

A dotted line is used when there is a break in the curve.

ANDOVER; Dr. POORE'S VILLAGE SYSTEM OF SEWAGE DISPOSAL.

A visit was paid to Andover by Mr. Frye and myself on 30th September 1901, and Dr. Poore's highly interesting system carefully inspected. By this plan the excreta and urine of about 100 people are collected daily in the early morning from the pails of 19 cottage privies, and the whole is immediately dug in under 6 inches of garden soil (for details *see* Dr. Poore's book on the subject "The Earth in relation to the preservation and destruction of Contagia," Longmans, 1902"; also his evidence given before the Commission, Vol. II., p. 510, *et seq.*).

We did not actually see this collection and digging carried out, but Dr. Poore assured us that it caused no offence whatever, provided it was done *daily*, as at Andover (Sundays excepted). The soil in the Andover garden is a deep loam (about 4 feet deep) overlying the chalk, and is therefore eminently suitable for the purpose in question. There was not the slightest smell or any unpleasantness at the time of our visit, and it was evident from the appearance of some patches of soil which the gardener dug up for us that the decomposition of the fæcal matter was going on rapidly.

Three-quarters of an acre of ground are available for 100 people, the land being used on a five years' cycle, and cultivated well during the period of rest from manuring. About nine months are required to manure a plot of 10 rods area (say, $\frac{1}{16}$ of an acre.) It is of interest to note, from the point of view of utilization of domestic sewage, that the crops of fruit and vegetables grown by Dr. Poore in this way are phenomenal.

Of course, as already stated, the garden soil at Andover is exceptionally well suited for the purpose. The weak point of the system would be shown by a long-continued frost rendering the ground too hard for cultivation; in such a case the excreta have to be collected into a heap admixed with ashes, and dug in later.

No slop water is allowed to get into the privy pails. The slop water of each cottage, after passing through a small basket filled with straw, which retains the grosser solids, finds its way along a wide perforated half-pipe placed on the surface of the ground, into which it then sinks to the drains. This arrangement could not, of course, be carried out so easily on a stiff non-porous soil as on the porous soil with underlying chalk at Andover.

In November 1901 a sample of well water from a shallow well in the middle of Dr. Poore's garden was drawn in duplicate by Mr. Kershaw (*see* his *Note* on the subject).* A reference to the accompanying figures of analysis shows that this sample was found to be exceedingly pure, chemically, and to maintain its aeration after being incubated. Judging from this one sample, therefore, the well had not, from a chemical point of view, suffered any damage from the excreta daily introduced into the garden soil. (Mr. Kershaw notes that at the time when the sample was drawn, fæcal matter was being dug in at a distance of about 50 feet from the well itself.) But this must not, of course, be taken as an argument for the advisability of sinking a well in ground near to which excreta are being disposed of.

* Part IV.: Engineering and Practical Report.

WELL IN DR. POORE'S GARDEN, ANDOVER, 1901.

(Dr. Poore's Village System of Sewage Disposal.)

No. of Sample	415	415
Nature of Sample	Well Water from Shallow Well in Dr. Poore's Garden.	Small Duplicate.
Drawn	Wednesday, 13th November 1901, 1.45 p.m.	—
Temperature of sample	9·5° C. (49° F.)	— —
Temperature of air	7·8° C. (46° F.)	— —
If jointed or incubated	—	Jointed and incubated, 14th November.
Analysed	14th November 1901.	3rd December 1901.
Parts per 100,000 *by weight.*		
Ammoniacal nitrogen (by distillation)	0·0002	—
Albuminoid nitrogen	0·005	—
Nitrous nitrogen	None.	None.
Nitric nitrogen	0·68	0·69
Total nitrogen by Kjeldahl, *with* reduction	Not tried.	—
Blank	—	—
"X" nitrogen	—	—
Organic nitrogen	?	—
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once.*	0·01	—
,, ,, ,, *after four hours.*	0·06	—
Oxygen absorbed from permanganate by sample incubated for 5 days at 26·7° C. (80° F.); *at once.*	0·02	—
,, ,, ,, *after four hours.*	0·14	— —
Smell after incubation	—	—
Chlorine	1·88	—
Gases: Parts per 1,000, *by volume.*		
Oxygen (by cuprous chloride)	3·90, 3·85 } Two observers.	3·7, 3·7, 3·7 } Three observers.
Remarks	Clear and colourless; minute quantity of whitish sediment, and one water flea, $\frac{3}{16}''$ long. No smell. Alkaline.	Clear and colourless. Very slight amount of brown sediment. No smell. *Note.*—It is of course difficult to say that these are absolute duplicates, so far as the oxygen is concerned. The standard tubes must at the time have been somewhat weakened, so that the readings, though strictly comparable, were probably rather too high.

DERBY COUNTY (MICKLEOVER) ASYLUM SEWAGE FARM.

A few days were spent by Mr. Kershaw in June, 1901, at the sewage farm of the Derby County Asylum, Mickleover, with the object of studying and drawing samples from a clay farm with a shallow surface soil. It will be seen from his Report that the depth of this stiff clay soil is only 3 to 4 inches, and that drains are laid in the clay subsoil at a depth of about 3 feet 6 inches. For details see the Engineering Report itself (Part IV. : Engineering and Practical Report).

The average dry-weather flow of sewage appears to be somewhere about 30,000 gallons, and as there is a population of 800 to 1,000, this gives 30 to 38 gallons per head; in addition, the liquid manure from the farm-yard is run on to the land from another outfall sewer. The whole irrigable area is 55 acres; hence (apart from the liquid manure) there are only 16 persons per acre of irrigable area, and only 530 gallons of sewage treated per acre, *on the assumption—for purposes of comparison—that each acre is sewaged continuously all the year round.* Mr. Kershaw, however, states in his Report that only about one acre at a time was being sewaged during his visit, *i.e.*, the particular acre for the day was taking 30,000 gallons of sewage, an excessive amount for land of such quality, especially as the farm is drained, and the sewage partly finds its way into the drains through cracks. On the other hand, the long rest which the land is allowed between two successive sewagings must result in the storing up of nitrate, which will then become available for the purification in the next sewaging. A reference to the analytical figures given by the various effluents examined bears out this conclusion.

Sewage.—Only one sample of sewage (No. 295) was examined. It was not particularly strong, so far as nitrogenous matter was concerned, but the 4-hours "oxygen absorbed" figure was excessively high in proportion. The centrifuge figure for solids was also high.

Effluents.—Six samples of effluent were examined, four of them in duplicate, and in some respects these were interesting.

No. 296 contained far more suspended solids (as measured by the centrifuge) than an effluent should do, and yet it was otherwise of fair quality, remaining sweet upon incubation without having exhausted much of its reserve of nitrate. Though little more than a trace of dissolved oxygen was present in it at the time of analysis, the figures for "oxygen absorbed" were by no means excessive.

No. 297 gave a very bad analysis indeed, and yet it had a clean smell when analysed and contained sufficient nitrate to keep it sweet upon incubation. Besides much other brown sediment, there were present in it pieces of straw up to half an inch in length, *which had reached the effluent drains through cracks in the ground.*

No. 298, which was the same effluent as No. 297, but drawn 300 yards lower down the ditch, was of very fair quality and kept perfectly upon incubation, while still retaining a large excess of nitrate. No. 297, therefore, had deposited much of its suspended solids during its passage along the ditch.

No. 299 was not by any means a good effluent either as regards suspended solids or organic matter generally, but it had no smell either when drawn or when analysed, and kept sweet upon incubation,—again because of its nitrate.

No. 300 bore the same relation to No. 299 as No .298 did to No. 297, and the same remarks apply here as there, only in a lesser degree, for this sample (No. 300) had not settled so much of its suspended matter in the ditch.

No. 301 was a very fair sample, taking it all over.

It is worth noting that the nitrite was always higher in the duplicate incubated samples of these effluents than in the original ones.

Speaking generally, therefore, the above effluents were better chemically than they looked, but the system on which the sewage was purified was faulty. The effluents really required to be run over a second piece of undrained land in order to filter off the matter in suspension. It would be interesting to have a few further samples from Mickleover during winter weather, when there would be less nitrification going on in the soil.

DERBY COUNTY (MICKLEOVER) ASYLUM SEWAGE FARM, 1901.

Sewage and Effluents.

No. of Sample	295	296	296	297
Nature of Sample	Crude Sewage (soapy and milky-looking).	Effluent, corresponding to Sewage No. 295. (Turbid, but no smell when drawn.)	Small Duplicate.	Final Effluent (dirty colour when drawn).
Drawn	Tuesday, 11th June 1901, 10.55 a.m.	Tuesday, 11th June 1901, 12 noon.	—	Wednesday, 12th June 1901, 11.15 a.m.
Temperature of sample	17·8° C. (64° F.)	10·0° C. (50° F.)	—	10·0° C. (50° F.)
Temperature of air	14·4° C. (58° F.)	14·4° C. (58° F.)	—	13·3° C. (56° F.)
If jointed or incubated	—	—	Jointed and incubated, 12th June.	—
Analysed	12th June 1901.	12th June 1901.	19th June 1901.	13th June 1901.
Parts per 100,000, *by weight.*				
Ammoniacal nitrogen (a) by direct Nesslerization.	Turbid.	Turbid.	—	Probably turbid.
Ammoniacal nitrogen (b) by distillation	3·66	0·27	0·40	0·37
Albuminoid nitrogen	1.20	0·18	0·15	0·56
Nitrous nitrogen	None.	0·03	0·09	0·07
Nitric nitrogen	Not done.	1·71	1·31	1·58
Total nitrogen, by Kjeldahl, *with* reduction.	5·74	2·49	—	3·30
Blank	(0·24 in 9·00)	(0·34 in 4·40)	—	(0·24 in 5·28)
"X" nitrogen	0·88	0·30	—	0·72
Organic nitrogen, by Kjeldahl, *with* reduction.	2·08	0·48	—	1·28
Organic nitrogen, by Kjeldahl, *without* reduction: Taking ammonia by distillation	1·28	0·17	—	1·00
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once*	6·50	0·65	0·35	1·64
" " " *after four hours.*	29·70	1·69	—	10·25
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once*	—	0·47	—	1·69
" " " *after four hours.*	—	1·89	—	10·75
Smell after incubation	—	Sweet; about 0·03 nitrite nitrogen.	Not noted. Must have been quite sweet.	Earthy; quite sweet. 0·01 to 0·015 nitrite nitrogen.
Chlorine	12·76	5·12	—	6·14
Parts per 100,000, *by volume.*				
Solids by centrifuge	434 (one minute).	65 (one minute).	—	Not practicable, on account of the pieces of straw present.
Gases: parts per 1,000, *by volume.*				
Oxygen (by cuprous chloride): When sample was analysed	—	About 0·5	—	None, or very slight trace.
Remarks	Very milky in appearance. Considerable brown sediment with white specks. Slight sewage smell. Alkaline.	This sample was slightly brown and turbid. It contained a considerable amount of light-brown sediment, among which was some fibrous matter. Clean smell. Alkaline.	After incubation this was a clear, almost colourless, liquid, containing some light-brown sediment. Alkaline.	Turbid and brown, with very much brown and straw sediment. Straws up to ½-inch long, but mostly about ⅜-inch and smaller. *These went through cracks into the effluent drains.* Clean smell. Alkaline.

DERBY COUNTY (MICKLEOVER) ASYLUM SEWAGE FARM, 1901.

Effluents.

297	298	298	299	300	300	301
SMALL DUPLICATE.	SAME EFFLUENT as No. 297, drawn 300 yards lower down the ditch.	SMALL DUPLICATE.	FINAL EFFLUENT (cloudy when drawn).	EFFLUENT taken 300 yards below outfall.	SMALL DUPLICATE.	EFFLUENT taken 600 yards below outfall.
—	Wednesday, 12th June 1901, 11·45 a.m.	—	Thursday, 13th June 1901, 10.55 a.m.	Thursday, 13th June 1901, 11.30 a.m.	—	Thursday, 13th June 1901, 12 noon.
—	11·1° C. (52° F.)	—	11·1° C. (52° F.)	11·1° C. (52° F.)	—	10·0° C. (50° F.)
—	13·3° C. (56° F.)	—	8·9° C. (48° F.)	10·0° C. (50° F.)	—	10·0° C. (50° F.)
ed and incu-d, 13th June. June 1901.	— 13th June 1901.	Jointed and incubated, 13th June. 21st June 1901.	— 14th June 1901.	— 14th June 1901.	Jointed and incubated, 14th June. 21st June 1901.	— 14th June 1901.
—	Turbid.	—	Turbid.	—	—	—
0·67	0·75	0·77	0·53	0·99	0·94	1·09
0·63	0·13	0·11	0·28	0·25	0·15	0·12
0·23	0·05	0·15	0·15	0·08	0·14	0·06
0·38	1·55	1·31 {Possibly a trifle too low.}	2·48	2·19 (?)	1·31	1·13
—	2·77	—	4.08	3·39	—	2·63
—	(0·24 in 4·46)	—	(0·24 in 6·47)	(0·34 in 5·87)	—	(0·34 in 4·63)
—	0·29	—	0·64	?	—	0·23
—	0·42	—	0·92	?	—	0·35
—	0·25	—	0·60	—	—	—
1·67	0·50	0·49	0·96	0·81	0·81	0·41
—	1·59	—	4·05	2·78	—	1·47
—	0·29	—	0·69	0·85	—	0·46
—	1·22	—	2·44	2·59	—	1·39
Earthy.	Sweet; 0·03 to 0·04 nitrite nitrogen.	—	Sweet; 0·04 to 0·05 nitrite nitrogen.	Sweet; about 0·01 nitrite nitrogen.	Sweet.	Sweet; about 0·01 nitrite nitrogen.
—	6·22	—	(a) 39·70 (b) 39·42	27·82	—	27·2
12·3 e minute).	—	—	40 (one minute).	28·5 (one minute).	—	27 (one minute).
—	{1·5, 1·0, 1·1} Three different observers.	—	{0·3, Trace} Two observers.	0·5 {Two observers}	—	{2·5, 2·2} Two observers
y clear; li-d brown, even en filtered. y much wn suspen-matter and w. Earthy ell.	This was turbid, with a slight greenish sediment. Clean smell. Alkaline. It is thus obvious that No. 297 must have deposited much solid matter in the ditch.	Liquid slightly brown. Small amount of greenish-brown sediment. Clean earthy smell.	This sample was opalescent, with green and brown sediment. Clean earthy smell. Alkaline. The large amount of combined chlorine is noteworthy.	Turbid brownish liquid, with a fair amount of brown sediment. Earthy smell. Strongly alkaline.	Clear, slightly brown liquid, with a fair amount of brown sediment. No smell. Alkaline.	Slightly turbid, but clearer than No. 300. Only slightly coloured. Very little sediment. Earthy smell. Strongly alkaline.

HEMSWORTH SEWAGE FARM, YORKSHIRE.

As at Mickleover, Mr. Kershaw spent a day or two in June 1901 at Hemsworth Sewage Farm, Yorkshire, which affords another instance of sewage treatment on land consisting of a shallow surface soil overlying stiff clay. The farm has been fully described in the Engineering Report,* and as the whole conditions attending it at the time of observation were so unfavourable, it is unnecessary to add much here; one or two of the notes made by Mr. Kershaw may, however, be shortly referred to again.

The soil of this farm is only $1\frac{1}{2}$ inches to $2\frac{1}{2}$ inches in depth, overlying about 6 feet of yellow clay, which rests upon boulder clay, but ashes have been dug into the beds (in which the farm is laid out) with the view of lightening the soil. The farm is underdrained at a depth of 3 feet. As was to be expected, the land cracks badly in summer.

The average dry-weather flow of sewage, which may be taken as domestic, is about 70,000 gallons, *i.e.*, 22 gallons per head of a population of 3,000. The sewage is settled and also occasionally treated with alumino-ferric before being run on to the land, where it receives a double treatment, *i.e.*, over two narrow strips of soil (cf. Engineering Report for the passage of the sewage direct to the drains).

The actual irrigable area being three acres (out of a total of four) each acre has to treat $\frac{70000}{3} = 23{,}300$ gallons of settled or precipitated sewage per day, under our usual assumption—*for purposes of comparison*—that the whole area is under sewage all the year round. It is unnecessary to add that this is an altogether excessive amount for land of the above character.

Only one sample of settled sewage, one of crude sewage, and two of final effluent were examined, the land from which the effluents were drawn being uncropped. The settled sewage was fairly strong and the crude distinctly so. The two samples of effluent were very bad, as was unavoidable from the disproportionate amount of sewage that the land received, and it is hardly necessary to enter into any detail with regard to them. Of course it must be borne in mind that no definite conclusions as to the daily working of a farm can be drawn from one or two chance analyses.

* Part IV.: Engineering and Practical Report.

HEMSWORTH SEWAGE FARM, 1901

Sewages and Effluents.

No. of Sample	291.	292.	293.	294.	294.
Nature of Sample	Settled Sewage.	Effluent corresponding to Sewage No. 291.	Crude Sewage (soapy; alumino-ferric being used).	Final Effluent (very bad smell and cloudy).	Small Duplicat
Drawn	Tuesday, 4th June 1901, 10.15 a.m.	Tuesday, 4th June 1901, 11.30 a.m.	Wednesday, 5th June 1901, 10.45 a.m.	Wednesday, 5th June 1901, 11.15 a.m.	—
Temperature of sample	11·7° C. (53° F.)	15·6° C. (60° F.)	13·3° C. (56° F.)	16·7° C. (62° F.)	—
Temperature of air	19·4° C. (67° F.)	21·1° C. (70° F.)	15·6° C. (60° F.)	16·1° C. (61° F.)	—
If jointed or incubated	—	—	—	—	Jointed and cubated June; *sa then grey-b* Opened
Analysed	5th June 1901.	5th June 1901.	6th June 1901.	6th June 1901.	June 1901.
Parts per 100,000, *by weight.*					
Ammoniacal nitrogen (a) by direct Nesslerization.	—	Turbid.	—	Turbid.	—
Ammoniacal nitrogen (b) by distillation.	5·39	3·47	(?) *12·88	*3·66 (?)	—
Albuminoid nitrogen	1·01	0·36	2·13	0·50	—
Nitrous nitrogen	Trace.	None.	None.	None.	—
Nitric nitrogen	Not done.	0·02	Not done.	0·01	—
Total nitrogen by Kjeldahl, *with* reduction.	7·14	4·22	(a) 11·48 (b) 11·51	(a) 4·20 (b) 4·12	—
Blank	(0·33 in 6·16)	(0·24 in 6·67)	June 26th (0·33 in 9·71) (0·34 in 9·74).	(0·24 in 6·64 and 6·52).	—
"X" nitrogen	0·74	0·37	(?)	(?)	—
Organic nitrogen by Kjeldahl, *with* reduction.	1·75	0·73	(?)	(?)	—
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once.*	1·95	1·09	6·84	1·30	—
,, ,, ,, *after four hours.*	6·60	4·03	20·37	5·36	—
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once.*	—	—	—	—	—
,, ,, ,, *after four hours.*	—	—	—	—	—
Smell after incubation	—	Very black and putrid, with strong smell of sulphuretted hydrogen. This went bad on the first day.	—	Very black and putrid, with sulphide.	—
Chlorine	12·26	11·70	12·0	12·36	—
Parts per 100,000, *by volume.*					
Solids by centrifuge	Centrifuge broken.	—	—	—	—
Gases: Parts per 1,000, *by volume.*					
Oxygen (by cuprous chloride)	—	—	—	—	—
Remarks	Very turbid, grey liquid, with a strong smell of sewage mixed with sage. Alkaline.	Opalescent, with rather considerable dark-brown and black deposit. Putrid smell. Faintly alkaline.	Very turbid grey liquid, with a large amount of almost black sediment which could not be properly broken up. Strong smell, more of mint or sage than of sewage. Alkaline. **Note.*—The above figure for ammoniacal nitrogen is clearly wrong (too high). A little carbonate of soda should have been added before the distillation.	Turbid, with considerable black and brown suspended matter. Very putrid smell. Faintly alkaline. **Note.*—Probably too high, no doubt again because of sulphide.	Very m blacken Very put and smell of sulphuret hydrogen. analysed.

LINDFIELD SEWAGE FARM (NEAR HAYWARDS HEATH, SUSSEX).

Two visits were paid to the Lindfield Sewage Farm, in May and June 1900, and samples of sewage and effluent were drawn each time. The farm is eight acres in extent, the soil being a stiff clayey one, overlying clay. Mr. Kershaw notes that the entire area of the farm is underdrained at a depth of 4 feet, and that the ground is very liable to crack in hot weather. The sewage is settled before being run on to the land.

Two samples of the sewage, which is purely domestic, were examined (Nos. 80 and 91). These were distinctly strong, both as regards nitrogen and oxidizable matter generally (see table of analysis).

The first drawn sample of effluent (No. 79), a *filtration* effluent from mangolds just appearing above ground, on the *upper* part of the farm, gave a very good analysis, but the low figures obtained—especially that for chlorine—indicated that subsoil water had found its way into the effluent channel; this, on further examination of the ground by Mr. Kershaw, was found to be the case. An effluent from the *lower* part of the farm, which discharged by a separate drain pipe into the same manhole as sample No. 79, was obviously bad and was therefore not sampled.

The second sample of effluent that was analysed (No. 92, drawn on 12th June, 1900) was not a good one. It had a slight sewage smell when it came to be analysed, contained a considerable quantity of organic matter and practically no nitrate, and became putrid upon incubation.

No further observations were made at Lindfield, but the few which have just been cited supply another instance of the difficulties attending the working of clay farms.

LINDFIELD (HAYWARD'S HEATH) SEWAGE FARM, 1900.

No. of Sample	79	80	91	92
Nature of Sample	Effluent from Upper Part of Farm (that from Lower Part was bad).	Settled Sewage. This does not correspond to No. 79.	Settled Sewage.	Final Effluent. Corresponding to Sewage No. 91. From osier beds.
Drawn	Monday, 21st May 1900, 3.35 p.m.	Monday, 21st May 1900, 3.50 p.m.	Tuesday, 12th June 1900, 12.55 Noon.	Tuesday, 12th June 1900, 2.30 p.m.
Temperature of sample	11·7° C. (53° F.)	11·7° C. (53° F.)	12·8° C. (55° F.)	11·7° C. (53° F.)
Temperature of air	16·7° C. (62° F.)	16·6° C. (62° F.)	26·7° C. (80° F.)	28° C. (84° F.)
Analysed	22nd May 1900.	22nd May 1900.	13th June 1900.	13th June 1900.
Parts per 100,000, *by weight.*				
Ammoniacal nitrogen (a) by direct Nesslerization.	Turbid.	13·26	16·06	3·87
Ammoniacal nitrogen (b) by distillation.	0·22	13·93	15·89	3·66
Albuminoid nitrogen	0·10	2·34	2·31	0·38
Nitrous nitrogen	None.	None.	None.	None.
Nitric nitrogen	0·07	Not done.	Not done.	0·09
Total nitrogen by Kjeldahl, *with* reduction.	0·37	18·14	20·38	4·01
Blank	(0·19 in 0·73)	(0·19 in 13·36)	(0·19 in 14·98)	(0·19 in 6·01)
"X" nitrogen	None. (−0·02)	1·87	2·18	None (?) (−0·03)
Organic nitrogen	0·10	4·21	4·49	0·38 (?)
Organic nitrogen by Kjeldahl, *without* reduction:				
(a) Taking ammonia by direct Nesslerization.	—	5·23	3·58	None (−0·09) (?)
(b) Taking ammonia by distillation	0·19	4·56	3·75	0·10 (?)
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once.*	0·21	5·65	7·01	0·79
" " " *after four hours.*	0·79	21·16	25·84	2·54
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once.*	0·06 } Six	—	—	0·91
" " " *after four hours.*	0·47 } days.	—	—	2·84
Smell after incubation	Sweet.	—	—	Blackened; smell of ammonium sulphide.
Chlorine	2·70	19·36	15·76	10·40
Gases: Parts per 1,000, *by volume.*				
Carbon dioxide (free)	16·41	—	—	—
Oxygen (boiled out)	5·70	—	—	—
Nitrogen	15·01	—	—	—
Remarks	Moderate amount of brown-red flocculent matter. The paper-filtered liquid had only the slightest brown tinge. Fishy-earthy smell; slightly alkaline. Only a small amount of lime in solution, and very little sulphate. A moderate amount of ferric iron in suspension. *Note.*—The foregoing analysis indicated that subsoil water had probably found its way into this effluent channel, which was afterwards verified.	Faint sewage smell. Dark-brown sediment in small amount. Alkaline.	Very considerable dark-brown deposit. Strong sewage smell. Alkaline.	When the bottle was opened, this sample was found to have a slight sewage smell. Brownish colour. A few particles of weed. Alkaline.

LUTON SEWAGE FARM.

The sewage farms of Winchester and Luton, both of which are on the chalk, were visited in the hope of getting an effluent. But, after the sewage has sunk into the soil at those places, nothing more is seen of it, and it is therefore impossible to draw an effluent in the usual way. It was felt, however, that if an effluent could by some means or other be obtained from sewage which had passed through a few feet of chalk, some comparative data with regard to purification would at all events be gained.

After a good deal of trouble Mr. Kershaw did succeed in collecting from the High Level Farm at Luton some effluents which had passed through different thicknesses of chalk, the method by which he did this being described in the Engineering Report.† The samples were drawn in November and December 1901. Too few analyses were made to allow of curves being drawn, so the Tables of Analysis must be referred to for details.

Soil.—The soil of the High Level Farm—a light loam—varies considerably in depth. Mr. Kershaw has noted that on the higher portions of the farm it is only from 4 inches to 10 inches deep, while on the lower parts it goes up to 3 feet or more. On the portion of land where the pit was dug from which the effluents were collected the surface soil was about 12 inches in depth* (this soil, however, was removed; *see* below).

Sewages.—Three analyses of the Luton sewage were made, the (chance) samples Nos. 411, 413 and 441 having been drawn *just before* the liquid began to filter through the chalk (as described by Mr. Kershaw). In its passage to the ground alongside of the artificial chalk pit the sewage must of course have undergone some settlement. It will be seen from the tables of analysis that these sewage samples were only moderately strong as regards nitrogenous matter, and that the "oxygen absorbed" figures were rather low.

Samples 411A and 413A represent the same sewages as Nos. 411 and 413, but filtered through paper before being analysed, the object of this filtration being to note the result of a mere mechanical straining upon the sewage, in order to be afterwards able to compare the purification effected by the first few feet of chalk. The above analyses of Nos. 411A and 413A show that this paper filtration reduced the organic nitrogen by about one-third, and the "oxygen absorbed" figures by one-sixth.

Effluents.—These were No. 409, which passed through 2 feet 6 inches to 3 feet of loose, rotten chalk (the surface soil having been previously removed); and Nos. 412, 414 and 442, which were drawn at the slightly greater depth of 3 feet 6 inches in the chalk. Heavy rain fell while the last sample was being drawn, and Mr. Kershaw states in his "Notes upon Samples"† that the liquid only took about a minute and a half to penetrate to the above depth, its passage being thus abnormally rapid.

It will be seen from the Tables of Analysis that (leaving No. 442 out of account in the meantime) the albuminoid nitrogen was not much less in those effluents than in the paper-filtered sewages, while the "oxygen absorbed" figure was in the case of No. 412 much higher and in No. 414 slightly lower. All three effluents contained phenomenal amounts of nitrate (up to 16 parts nitric nitrogen per 100,000), washed out from what had been accumulating in the soil and upper chalk (?) during the previous resting of the ground. The determination of organic nitrogen by the *Kjeldahl* method in the presence of such excessive quantities of nitrate is not an easy matter, and too much weight must therefore not be laid upon the figures given for it. Sample No. 442, which was exceedingly dilute in other respects, actually contained

* *Note.*—On the Luton Low Level Farm there are 10 inches to 15 inches of light loam over gravel of varying depth, the gravel overlying the chalk.

† Part IV.: Engineering and Practical Report.

24 parts of nitric nitrogen per 100,000. This last sample showed very much greater purification (with respect to sewage No. 441) than the other three effluent samples, though this was probably due *in part* to the heavy rain which fell while it was being drawn, and by which it must have been appreciably diluted.

The results of these few estimations show that the sewage underwent comparatively little purification in its passage through the three feet of chalk from which the surface soil had been removed, though it carried with it such large quantities of stored-up nitrate as to prevent subsequent putrescence. This store of nitrate, however, would obviously soon become exhausted, unless allowed to renew itself by frequent resting of the ground. Samples Nos. 409 and 412 were noted by Mr. Kershaw as having a slight sewage smell when drawn, but all the three samples of effluent smelt sweet on the following day. A few estimations of the amounts of nitrate in the soil and chalk are appended (cf. Tables of Analysis), from which it will be seen that the top soil was at the time rather rich in nitrate, but that the quantity decreased as one penetrated the chalk (the greatest depth tested was about one foot below the upper surface of the chalk).

Small duplicate samples of effluents Nos. 409, 412, 414 and 442 were partially analysed after being jointed and incubated, the result showing a great reduction of nitrate in every case excepting the last—a further proof that the sewage in its passage through the chalk had not undergone very much purification.* It should, however, be borne in mind here that, owing to the difficulty of sampling, there is uncertainty about the first three of these having been true duplicates; indeed they were probably not so. The large bottle was in each case filled from the small one, and the small one therefore filled last. It required from 35 minutes to several hours to draw a given sample in duplicate.

The foregoing results are of course much too few in number to allow of any authoritative conclusions being drawn from them. But, as it is well known that chalk is fissured in all directions, they at least indicate that great caution should be exercised in the sinking of wells, the water of which might by any possibility be affected by a sewage effluent from such ground.

Spring and Well Waters.

With the object of testing this last point (possible pollution of spring and well waters in the neighbourhood of a chalk sewage farm), three samples of spring water, Nos. 240, 241 and 243, were drawn from springs at some watercress beds about 200 yards from the low-level sewage farm; and three samples of a well water, Nos. 242, 244 and 410, were taken from a well 20 feet deep, in a cottage garden about 90 yards from the same farm.

The Tables of Analysis show that the *spring* water was good as a drinking water from a chemical point of view, though No. 243 did not maintain its aeration very well after being incubated, this proving the presence of a little oxidizable matter of one kind or another (probably vegetable; cf. Bacteriological Report).† The variation in the amounts of chlorine (2·12 and 3·42 parts per 100,000) in samples Nos. 240 and 243, both of which were drawn from the same spot, is also noteworthy, and requires further elucidation.

Unfortunately, as regards the samples of *well* water (which showed pollution), the results are inconclusive, as it turned out that the well was liable to pollution from fæcal matter applied as manure in the garden in the immediate neighbourhood of the well itself.

It would be of distinct interest if time allowed of some further investigation of the various points indicated in this short Report.

---

* The large amount of nitrite remaining in the incubated duplicate of No. 414 is very striking.

† Part III.: Bacteriological Report, by Dr. Houston.

LUTON SEWAGE FARM.

TABLES OF ANALYSIS.

INDEX.

	PAGE.
Sewage and Effluents, Nos. 409, 411, 411A	254
,, Nos. 412, 413, 413A, 414	255
,, ,, Nos. 441, 442	256
Spring Water, Nos. 240, 241, 243	258
Well Water, Nos. 242, 244, 410	259
Nitrate in Surface Soil and Uppermost Chalk	260

LUTON SEWAGE FARM, 1901.

Sewage and Effluents.

No. of Sample	409.	409.	411.	411a.
Nature of Sample	Filtration Effluent which had passed through 2 feet 6 inches to 3 feet of chalk.	Small Duplicate.	Sewage just before filtering through the chalk.	Same Sample as No. 411, but filtered before analysis, partly through German and partly through Swedish paper.
Drawn	Tuesday, 5th Nov. 1901, 3.30 p.m.	—	Thursday, 7th Nov. 1901, 1 p.m.	—
Temperature of sample	10·0° C. (50° F.)	—	11·1° C. (52° F.)	—
Temperature of air	4·4° C (40° F.)	—	10·0° C. (50° F.)	—
If jointed or incubated	—	Jointed and incubated 6th Nov.	—	—
Analysed	6th Nov. 1901.	16th Nov. 1901.	8th Nov. 1901.	8th Nov. 1901.
Parts per 100,000, *by weight.*				
Ammoniacal nitrogen, by distillation	1·50	—	5·66	5·48
Albuminoid nitrogen	0·51	—	0·88	0·54
Nitrous nitrogen	None.	0·01	Not done	0·10
Nitric nitrogen	13·59 { 7th Nov. Probably a little low. }	5·67	,,	0·14
Total nitrogen, by Kjeldahl, *with* reduction.	17·41	—	7·65	7·11
Blank	(0·30 in 25·74)	—	(0·33 in 5·95)	(0·33 in 5·55)
"X" nitrogen	1·80 } Probably too high.	—	1·11	0·85
Organic nitrogen by Kjeldahl, *with* reduction.	2·31 }	—	1·99	1·39
Oxygen absorbed from permangamate at 26·7° C. (80° F.); *at once.*	2·40	—	5·11	4·38
,, ,, ,, *after four hours.*	8·02	—	9·72	7·76
Oxygen absorbed from permangamate by sample incubated for 5 days at 26·7° C. (80° F.); *at once*	1·14	—	—	—
,, ,, ,, *after four hours.*	4·21	—	—	—
Smell after incubation	Strong but sweet; trace of nitrite.	—	—	—
Chlorine	11·69	—	13·82	—
Parts per 100,000, *by volume.*				
Solids by centrifuge	Too much chalk present.	—	Not done. Large lumps of chalk present.	—
Gases: parts per 1,000, *by volume.*				
Oxygen (by cuprous chloride): When sample was analysed	From 0·5 to 1	—	—	—
Remarks	Turbid, with considerable chalky sediment. Smell noted as (1) distinct sewage smell; (2) fishy; (3) seaweed or earthy, by three different observers. Alkaline. The turbidity was due mostly to chalk. A very large amount of lime in solution and also of sulphate; a small but appreciable amount of ferric iron and a trace of ferrous iron.	After incubation the sediment was brown. Clean, earthy smell. Probably these two samples of No. 409 were only approximate duplicates, from the difficulty of drawing them.	Turbid brownish liquid, with a fairly large amount of sediment, and several pieces of chalk the size of a small marble. Faint sewage smell. Alkaline.	This filtered sewage was slightly brown and slightly turbid, evidently with lime. It took about four hours to filter.

LUTON SEWAGE FARM, 1901.

Sewage and Effluents.

412.	412.	413.	413a.	414.	414.
EFFLUENT from Sewage No. 411, after it had passed through 3 feet 6 inches of loose chalk.	SMALL DUPLICATE.	SEWAGE drawn just before passing through the chalk.	SAME SAMPLE as No. 413, after being filtered through Swedish paper.	EFFLUENT after passing through 3 feet 6 inches of chalk.	SMALL DUPLICATE.
Thursday, 7th Nov. 1901, 1.15 p.m.	—	Monday, 11th Nov. 1901, 12.30 noon.	—	Monday, 11th Nov. 1901, 1 p.m.	—
9·4° C. (49° F.)	—	11·7° C. (53° F.)	—	10° C. (50° F.)	—
10·0° C. (50° F.)	—	12·2° C. (54° F.)	—	12·2° (54° F.)	—
—	Jointed and incubated 8th Nov.	—	—	—	Jointed and incubated 12th Nov.
8th Nov. 1901.	27th Nov. 1901.	12th Nov. 1901.	12th Nov. 1901.	12th Nov. 1901.	2nd Dec. 1901.
2·51	1·73	6·37	6·07	1·15	2·18
0·41	0·18	0·78	0·57	0·42	0·31
0·08	0·22	Not done.	None.	1·07	0·76
(?) 16·10 {1 c.c. / 1 day}	{14·77 (1 day) / 14·61 (2 days)}	,,	Not done.	15·97	{8·30 (1 day). / 9·37 (2 days).}
21·82	—	8·19	7·30	18·45	—
(0·30 in 16·24)	—	(0·33 in 6·34)	(0·33 in 5·69)	(0·30 in 13·78)	—
(?) 2·72	—	1·04	0·66	None (?)	—
(?) 3·13	—	1·82	1·23	0·42 (?)	—
2·76	0·82	2·80	1·44	2·35	1·91
13·70	—	7·33	6·12	5·61	4·41
1·51	—	—	—	1·90 } 7 days.	—
4·69	—	—	—	4·09 } 7 days.	—
Sweet, earthy; about 0·01 nitrite nitrogen.	—	—	—	Sweet, earthy; about 1·26 nitrite nitrogen.	—
13·30	—	—	12·42	11·70	—
Too chalky.	—	126·0 Probably some of this was fine chalk. It was not tested.	—	Too chalky.	—
None	—	—	—	Less than 1·0	—
Turbid, with much chalky sediment. Clean earthy smell. Alkaline.	Clear, with a slight brown tinge. Dark brown sediment. Clean earthy smell. Here again there is the uncertainty about these being real duplicates.	Turbid greyish-brown liquid, with greyish sediment, which was not in very large quantity for a sewage. Distinct sewage smell. Alkaline.	This filtered sewage was slightly turbid and slightly brown, with a sewage smell.	Opalescent and milky, with a small amount of sediment. Clean smell. Alkaline.	Fairly clear. Liquid had a slight brown tinge. Considerable brown sediment. Clean smell. Again uncertainty about these being real duplicates. *Note.*—In this small bottle, No. 414, the stopper had not held, and most of the mercury of the joint had got into the bottle.

LUTON SEWAGE FARM, 1901.

Sewage and Effluent.

No. of Sample	441	442	442
Nature of Sample	Sewage just before going through the chalk.	Effluent corresponding to No. 441. (Heavy rain).	Small Duplicate. Transferred from the original sample after the bottle had been standing partly empty for about five hours.
Drawn	Thursday, 12th December 1901, 3.30 p.m. (Heavy rain).	Thursday, 12th December 1901, 3.30 p.m.	—
Temperature of sample	5·0° C. (41° F.)	3·9° C. (39° F.)	—
Temperature of air	7·2° C. (45° F.)	7·2° C. (45° F.)	—
If jointed or incubated	—	—	Jointed and incubated, 13th December 1901.
Analysed	13th December 1901.	13th December 1901.	3rd January 1902.
Parts per 100,000, *by weight.*			
Ammoniacal nitrogen, by distillation	2·83	0·15	—
Albuminoid nitrogen	1·11	0·16	—
Nitrous nitrogen	Not done } These should have been tested for.	0·02	None.
Nitric nitrogen	,, } These should have been tested for.	24·52	* 23·4
Total nitrogen, by Kjeldahl, *with* reduction.	6·45	24·86	—
Blank	(0·25 in 4·95)	(0·34 in 36·84)	—
"X" Nitrogen	2·51 (?)	0·01 } Probably too low.	—
Organic nitrogen, by Kjeldahl, *with* reduction.	3·62 (?)	0·17 } Probably too low.	
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once*	3·90	0·62	0·29
,, ,, ,, *after four hours.*	13·04	2·13	—
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once.*	—	0·58 } Six days.	—
,, ,, ,, *after four hours.*	—	1·69 } Six days.	
Smell after incubation	—	Sweet. No nitrite.	—
Chlorine	6·46	12·04	—
Parts per 100,000, *by volume.*			
Solids by centrifuge	289·0 This was apparently a sewage sediment.	26·0	—
Gases: parts per 1,000, *by volume.*			
Oxygen (by cuprous chloride)	—	Not done. Probably too turbid, or perhaps because of smell.	—
Remarks	Turbid, with—for a sewage—a small amount of brown sediment. Faint or doubtful sewage smell. Alkaline.	Turbid, slightly brown liquid. Not much sediment. Musty smell. Alkaline.	After incubation this liquid was brown and clear, with a fair amount of brown-grey sediment. No smell. Alkaline.

* The figure actually noted was 2·34, but there must have been an error in the decimal, for the following reason:—

On 17th February, 1902, a small bottleful was taken from the above large bottle, which had been standing half full since 13th December, 1901. This small sample was jointed on 17th February, and incubated until 30th May, when it was analysed. It gave:—

Nitrous nitrogen—None.

Nitric nitrogen—

On 1, c.c.	On 2, c.c.
24·4†	25·2

"Oxygen absorbed" from permanganate at 26·7° C. (80° F.); *at once*—0·22.

† There must have been a slight loss of nitrogen here after reduction by the zinc-copper couple, for ammonia could be smelt faintly when the liquid was being transferred for distillation.

SAMPLES FROM LUTON, 1901.

(*a*) Water from Watercress Bed Springs.

(*b*) Well Water from Cottage Garden.

SAMPLES FROM LUTON, 1901—(a) Water from Watercress Bed Springs.

No. of Sample	240	241	243	243
Nature of Sample	Spring Water from Watercress Beds below Sewage Farm.	Sample taken from a Mixture of Springs at Watercress Beds.	Water from Spring in Watercress Beds (*i.e.*, from same source as No. 240), filtered before analysis.	Small Duplicate.
Drawn	Tuesday, 19th March 1901, 12 noon.	Tuesday, 19th March 1901, 12.15 noon.	Wednesday, 27th March 1901, 3.30 p.m.	—
Temperature of sample	7·8° C. (46° F.)	8·3° C. (47° F.)	7·8° C. (46° F.)	—
Temperature of air	3·3° C. (38° F.)	3·9° C. (39° F.)	3·3° C. (38° F.)	—
If jointed or incubated	—	—	—	Jointed and incubated, 27th Mar.
Analysed	Siphoned for analysis, 21st March 1901.	20th March 1901.	27th March 1901.	2nd April 1901.
Parts per 100,000, *by weight.*				
Ammoniacal nitrogen (a) by direct Nesslerization.	—	Turbid.	—	—
Ammoniacal nitrogen (b) by distillation.	0·0011	0·01	0·002	—
Albuminoid nitrogen	0·0057	0·005	0·006	—
Nitrous nitrogen	None.	None.	None.	None.
Nitric nitrogen	0·60	0·74	0·64	0·63
Total nitrogen by Kjeldahl, *with* reduction.	0·56	0·82	0·67	—
Blank	(0·16 in 0·97)	(0·20 in 1·41)	(0·20 in 1·18)	—
"X" nitrogen	?	0·065 ?	0·022	—
Organic nitrogen by Kjeldahl, *with* reduction.	?	0·07 ?	0·028	—
Organic nitrogen by Kjeldahl, *without* reduction;				
Taking ammonia by distillation.	0·021	None.	—	—
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once.*	Too small to estimate.	None.	0·04	—
" " " *after four hours.*	0·06	0·10	0·12	—
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once*	Too small.	None.	0·03	—
" " " *after four hours*	0·07	0·11	0·24	—
Smell after incubation	Strong, but sweet. No nitrite.	Strong, but sweet.	Sweet.	—
Chlorine	2·12	1·76	3·42	—
Gases: parts per 1,000, *by volume.*				
Oxygen (by cuprous chloride): When sample was analysed	5·75, 5·70 Two observers.	6·7, 6·5 Two observers	5·2 Two observers	2·75
Remarks	Clear and colourless. The liquid was siphoned from green cress leaf and white root before analysis. Leathery (cress?) smell. Alkaline.	Colourless, slightly turbid liquid (turbidity probably due to lime). Practically no sediment. No smell. Alkaline. Very considerable amount of lime in solution, but only a little sulphate. No iron.	Clear and colourless. No real sediment, but a number of fragments of green leaves, roots, &c., in suspension. No smell.	After incubation this was clear and colourless, with floating particles of green leaf and white root; also small brownish particles. Clean smell.

SAMPLES FROM LUTON, 1901—(b) Well Water.

242	244	244	410	410
WELL WATER TAKEN FROM WELL 20 feet deep, in cottage garden. Two feet of water in well.	WELL WATER FROM SAME SOURCE AS No. 242. Filtered before analysis.	SMALL DUPLICATE (Analysed without the sediment, practically speaking).	WELL WATER FROM SAME SOURCE AS Nos. 242 AND 244. One foot three inches of water in well.	SMALL DUPLICATE.
Tuesday, 19th March 1901, 12.45 noon.	Tuesday, 26th March 1901, 3.45 p.m.	—	Thursday, 7th November 1901, 11.15 a.m.	—
7·8° C. (46° F.)	7·8° C. (46° F.)	—	10° C. (50° F.)	—
3·3° C. (38° F.)	2·8° C. (37° F.)	—	8·9° C. (48° F.)	—
—	—	Jointed and incubated, 27th March.	—	Jointed and incubated, 8th November.
20th March 1901.	27th March 1901.	3rd April 1901.	8th November 1901.	26th November 1901.
—	—	—	—	—
0·0026	0·0041	—	0·002	—
0·0396	0·0308	—	0·023	—
None.	None.	None.	None.	None.
0·99	0·95	0·95	1·00	0·99 (one day) 1·01 (two days).
1·04	1·05	—	—	—
(0·16 in 1·67)	(0·16 in 1·69)	—	—	—
0·01	0·065	—	—	—
0·05	0·096	—	—	—
Less than blank, though done in the usual way.	0·068	—	—	—
0·13	0·02	0·06	0·07	0·02
0·35	0·30	—	0·29	—
0·03 0·17	0·08 0·23	— —	0·13 0·16	— —
Leathery smell. No nitrite.	Slight leathery smell. No nitrite.	—	Sweet.	—
3·80	3·92	—	4·04	—
3·4	3·7, 3·75 } Two observers.	2·75	3·4*	None.
Colourless. Small amount of light brown suspended matter. Earthy smell. Much lime precipitated on boiling.	Clear and colourless, with a small amount of light brown and grey sediment. Leathery smell. Alkaline.	Colourless. A little very light brown sediment, which was not taken for analysis. No smell.	Clear, colourless and bright. Minute amount of whitish sediment. Very slight earthy smell. Alkaline. * This reading is probably rather too high, the standards being old.	Clear and colourless. Minute quantity of white sediment. Very slight earthy smell, or none.

LUTON SEWAGE FARM, 1901.

Chemical Examination of Luton Sewage Farm Surface Soil and Chalk for Nitrate.

In view of the large quantities of nitric nitrogen found in the foregoing effluents drawn from a few feet below the surface of the chalk, examinations for nitrate were made in the following samples of the surface soil and of the chalk drawn at different depths near to the surface. This ground had been last sewaged 10 days before the soil and chalk samples were drawn.

Sample No. 1.

Surface soil, drawn at a depth of 6 inches to 8 inches on 11th November 1901.

21*st November* 1901.—A good even sample was made and ground up roughly, and 50 grammes of it were well shaken up in a flask with 833·9 grms. hot water. The liquid was allowed to stand for, say, a couple of hours or so, the clearer portion siphoned into another flask, and the nitrate determined by the zinc-copper couple in filtered and unfiltered portions of this, both of these solutions being very muddy (although slow filtering paper was used for the filtration).

Found, per 100,000 *parts soil.*	Unfiltered (25 cc. taken for estimation).	Filtered (25 c.c. taken).
(A.)—Nitric nitrogen (including any nitrous) -	6·34	6·32

28*th November* 1901.—A fresh solution of the same sample of soil was made in the same way as above, using 25 grms. soil and 570·3 grms. water. After shaking up with hot water as usual, the solution was left to stand with its own mud in a stoppered flask at room temperature until Saturday, 7th December. Even then it was not quite clear. The liquid was now siphoned off.

Found per 100,000 *parts soil.*	Unfiltered (25 cc. taken).	Filtered. (25 cc. taken).
(B.)—Nitric (including any nitrous) nitrogen -	5·41	5·41

These figures appear to show that some de-nitrification had been taking place in B.

Sample No. 2.

Chalk taken at a depth of 1 inch to 4 inches below surface soil on 11th November 1901.

15*th November* 1901.—This was sampled and ground up. Then 10·086 grms. were ground to a cream with 996 grms. cold water, and the whole was well shaken, say, half-a-dozen times. The mud was then allowed to settle for a couple of hours or so, and the nitrate determined as in Sample No. 1.

Found per 100,000 *parts soil.*	Unfiltered (25 cc. taken). (very turbid). 15th November.	Filtered (100 cc. taken). 16th November.
(C.)—Nitric (including any nitrous) nitrogen -	3·25	8·13

18*th November.*—In another portion of the solution the liquid was poured off the mud as completely as possible, and the nitrate again determined.

	(*a*) Unfiltered (50 cc. taken).	(*b*) Unfiltered (100 cc. taken).
Found - - - - - - - - -	3·64	3·58

The residue from estimation (*a*) was again treated with the couple, and gave 0·49 part nitric nitrogen. But this figure (0·49 per 100,000) corresponded to only 0·3 cc. of the dilute standard ammonium chloride used for nesslerizing, hence not much importance can be attached to it.

25*th November* 1901.—On account of the discrepancy in the above figures a fresh portion of the powdered sample, weighing 50 grms., was ground to a cream with 873 grms. hot water, the mixture transferred to a flask and shaken up well as usual, and then allowed to settle for about two hours. From the less thick portion of the solution some was pipetted off, and the nitrate determined in the filtered and unfiltered portion of this :—

Found.	Unfiltered (25 cc. taken)	Filtered (25 cc. taken).
(D.)—Nitric (including any nitrous) nitrogen	3·28	4·05

Both of these solutions were very turbid.

Omitting, therefore, the figure 8·13 in the second estimation as being probably wrong, the estimations in the freshly-made unfiltered liquids agree fairly well, viz., 3·25 and 3·28. The third and fourth estimations (3·64 and 3·58) and the sixth estimation (filtered) (4·05) appear to show oxidation while the mud stood with water, which is the opposite of what took place in cases A. and B. (sample No. 1).

Sample No. 3.

Taken 1 foot below *Sample No.* 2, on 11th November 1901.

21*st November* 1901.—This was sampled and powdered like Nos. 1 and 2, and 50 grms. of it were ground to a cream with 916 grms. of hot water, and the whole shaken. After settling for about two hours as usual, the nitrate was determined in the filtered and unfiltered portions.

Found per 100,000 *parts soil.*	Unfiltered (25 cc.) taken.	Filtered (25 cc.) taken.
(E.)—Nitric (including any nitrous) nitrogen -	2·35	2·84

The filtered portion was in this instance fairly clear.

25*th November* 1901.—A fresh solution of the above powdered sample was made up to-day, using 50·0 grms. chalk, and 874·8 grms. water.

Found.	Unfiltered (25 cc.) taken.	Filtered (25 cc.) taken.
(F.)—Nitric (including any nitrous) nitrogen -	2·68	3·21

The filtered solution was in this case very turbid.

27*th November* 1901.—Another fresh solution was made up to-day with 25 grms. chalk and 658·8 grms. water, and was allowed to settle for about two hours.

Found.	Unfiltered (50 cc.) taken.
(G.)—Nitric (including any nitrous) nitrogen - - -	2·39

Here again the agreement is fairly good in the unfiltered portions (2·35, 2·68, and 2·39), but again filtration apparently means oxidation (2·84 and 3·21).

Conclusion.—The top soil (No. 1) was thus rather rich in nitrate, and the nitrate decreased in the chalk with increasing depth.

SANDHURST SEWAGE FARM.

During Mr. Kershaw's first stay at Aldershot Camp in April, 1900, he took the opportunity of visiting the small farm at Sandhurst, and of drawing one sample of sewage, one of a first field irrigation effluent over rye-grass, and one of a final percolation effluent, which were analysed.

The soil and sub-soil of this farm are given by Mr. Kershaw as being similar to those of Aldershot Camp farm, *i.e.*, they are sand, but with a greater depth of top-soil. The under-drains are 3 feet deep. The sewage flow per 24 hours is about 15,000 gallons, from a population of 600–700, which works out to about 23 gallons per head. The irrigable area being 13 acres, each acre would treat 1,100 gallons, *supposing it were under sewage all the year round*—a very small dose. The sewage is settled in tanks before being run on to the land.

No real deductions can be drawn from so few (chance) analyses, but it may just be noted that both the sewage and the two effluent samples were rather weak, that the final effluent was but little better than the first field one, and that neither effluent withstood the incubation test as judged by smell. The final effluent contained a good deal of weed (from the drain pipes ?) tinged red by oxide of iron.

Note.—Of the two *Kjeldahl* methods for determination of organic nitrogen, the one *without* reduction clearly gave the better results in samples Nos. 61 and 63; in No. 62 the agreement between the two methods was good.

SANDHURST SEWAGE FARM, 1900.

No. of Sample	61.	62.	63.
Nature of Sample	Settled Sewage.	First Effluent over Rye Grass.	Final (Percolation) Effluent.
Drawn	Wednesday, 4th April 1900, 12 noon.	Wednesday, 4th April 1900, 1.30 p.m.	Wednesday, 4th April 1900, 3 p.m.
Temperature of sample	8·9° C. (48° F.)	13·3° C. (56° F.)	10° C. (50° F.)
Temperature of air	—	—	—
If jointed or incubated	—	—	—
Analysed	5th April 1900.	5th April 1900.	6th April 1900.
Parts per 100,000, *by weight.*			
Ammoniacal nitrogen (a) by direct Nesslerization.	4·20	1·65	0·93
Ammoniacal nitrogen (b) by distillation	4·71	1·73	0·96
Albuminoid nitrogen	0·81	0·27	0·22
Nitrous nitrogen	None.	None.	0·12
Nitric nitrogen	Not done.	None.	0·26
Total nitrogen by Kjeldahl, *with* reduction (after nitrite correction).	5·65	2·30	1·58
Blank	(0·23 in 4·33)	(0·22 in 3·56)	(0·32 in 2·52)
Correction for nitrite	None.	None.	+ 0·06
"X" nitrogen	0·13 (?)	0·30	0·02 } These must be wrong.
Organic nitrogen by Kjeldahl, *with* reduction.	0·94 (?)	0·57	0·24 } These must be wrong.
Organic nitrogen by Kjeldahl, *without* reduction:			
Taking ammonia by distillation	1·45	0·68	0·51
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once.*	1·48	0·70	0·88
,, ,, ,, *after four hours.*	5·37	2·58	2·56
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once*	—	0·72	0·84
,, ,, ,, *after four hours.*	—	1·90	2·23
Smell after incubation	—	Putrid.	Putrid.
Chlorine	6·16	4·50	4·18
Gases: Parts per 1,000, *by volume.*			
Carbon dioxide (free)	—	22·04	44·34
Oxygen (boiled out)	—	0·15	0·03
Nitrogen	—	14·06	18·83
Remarks	This sample contained only a very small amount of light-brown suspended matter. It had more of a soapy than a sewage smell. Alkaline.	This was distinctly opalescent, but contained only a little brown-black flocculent matter. Clean earthy smell. Neutral, turning to alkaline. Very little lime, and only a little sulphate in solution.	Opalescent to muddiness, and containing a good deal of weed tinged brown-red by oxide of iron. Fishy-earthy smell. Slowly acid, but alkaline on boiling. Only a little lime and a little sulphate in solution.

WOKING SEWAGE FARM.

In October 1900 a visit was paid to the Woking Sewage Farm by Mr. Kershaw and myself, with the object of inspecting the late Mr. Santo Crimp's settling tanks, which are provided with an arrangement for upward filtration of the settled sewage, previous to its distribution over the land; and advantage was taken of this visit to draw small chance samples of sewage and effluent for partial examination.

A reference to the accompanying table of analysis will show that the sewage was very strong and the effluent well nitrated and of very high class. After nearly three weeks' incubation it still retained a little dissolved oxygen. The dissolved oxygen was not determined at the time of drawing, but the effluent being a percolation one was probably not very highly aerated then.

Woking farm would be an interesting place on which to make a few further observations, especially having regard to the nature of the soil, which is very fine sand (Bagshot sand).

WOKING SEWAGE FARM, 1900.

No. of Sample	1.	2.	3.	
Nature of Sample	Sewage from Sewage Well (small sample).	Final Effluent from Lowest Manhole (small sample).	Sewage drawn by Mr. Santo Crimp's man from weir at end of E. tank, 50 hours after any rain.	Artificial Storm Waters.
Drawn	Friday, 19th October 1900, 3 p.m.	Friday, 19th October 1900, 2.30 p.m.	Monday, 19th November 1900, 2.30 p.m.	
If jointed or incubated	—	Jointed, 20th October; on top of incubator part of time; inside, 23rd October.	—	
Analysed	20th October 1900.	9th November 1900.	26th November 1900.	
				These were made by diluting the Woking Sewage, No. 1, 31·24 times, *i.e.*, 15 c.c. sewage + 468·6 c.c. tap water. This dilution corresponds to 0·107 albuminoid nitrogen per 100,000, which is below the M. and I. standard (0·118).
Parts per 100,000, *by weight.*				
Ammoniacal nitrogen by distillation	11·50	0·15	—	
Albuminoid nitrogen	* 3·44	0·04	—	
Nitrous nitrogen / Nitric nitrogen	Not enough of sample. Almost certain to be none.	4·02	—	Incubated two portions for six days (a) at atmospheric temperature, and (b) at 26·7° C. (80° F.).
Organic nitrogen by Kjeldahl, *without* reduction:				
Taking ammonia by distillation	7·89	—	—	—
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once.*	—	—	—	20th October 0·03 * before incubation. * This is probably too low.
" " " *after four hours.*	—	—	—	—
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once.*	—	—	—	(a) 0·16 (b) 0·55 after six days
" " " *after four hours.*	—	—	—	—
Smell after incubation	—	Slightly earthy	—	Both (a) and (b) were putrid.
Chlorine	—	—	12·23	—
Gases: Parts per 1,000, *by volume.*				
Oxygen (by cuprous chloride)	—	About 1·0. Standards weakened.	—	—
Remarks	Putrid, with considerable brown deposit. * A correction for the albuminoid nitrogen had to be introduced here, as the distillation apparatus was not working satisfactorily at the time.	When taken from the incubator, this had a slight earthy smell. The liquid contained a very few dark brown flocculi. The above is an exceedingly good effluent.	There was very little sediment in this sample of sewage.	This again shows that a diluted sewage, even below the provisional M. and I. albuminoid nitrogen standard, will not keep sweet upon incubation.

WORSLEY SEWAGE FARM (NEAR MANCHESTER).

This farm was kept under partial observation by Mr. Kershaw during the latter half of May 1901, *i.e.*, concurrently with his second visit to Altrincham.

The soil on the northern portion of the farm consists of gravel and sand, and is described in the Engineering Report as "fairly suitable for sewage purification." But, excepting that one sample, No. 287, was drawn from gravelly soil, this area was left alone, the object of going to Worsley being to test the effect of peat land upon sewage; the southern portion of the farm consists of peat, with practically no surface soil. Mr. Kershaw states in his Report that at a depth of 5 to 6 feet below the surface of the peat there is found a bed of exceedingly fine white sand, but this is slightly lower than the level of the drain pipes, whose depth is 5 feet.

The average dry-weather flow of sewage is 300,000 gallons, a considerable portion of which consists of dye and bleach refuse. The population draining to the farm being 10,000, the dry-weather flow (inclusive of trade refuse) is thus equal to 30 gallons per head. Forty acres of the farm are laid out for irrigation, though only 22 acres were available, owing to cropping, at the time of Mr. Kershaw's visit. Taking the size at 40 acres, this gives 250 persons per acre (*plus* the unknown quantity of trade refuse). With the area under actual irrigation at any one time, some 15,000 to 23,000 gallons per acre are treated in 24 hours. But if we make, *for purposes of comparison*, our usual assumption, *then each acre at Worsley treats about* 7,500 *gallons per* 24 *hours all the year round.*

Peat being of the nature of a sponge, it is not suitable for sewage purification, because of the difficulty of draining it and the consequent lack of aeration. Comparatively few samples therefore were drawn from the Worsley farm,—just sufficient to indicate the difference between a sewage effluent from peat and one from gravelly soil.

Nature of Sewage.

The sewage is *crude*, without any screening or settling, and contains a good deal of dye and bleach refuse. Only *three* samples were examined, viz., Nos. 277, 281 and 285; the two last smelt of sulphuretted hydrogen when analysed, and contained very considerable amounts of black sediment. Taking the three samples together, the nitrogenous matter was only moderate in amount, but the "oxygen absorbed" figures, especially in No. 281, were relatively high. All the samples contained dye refuse, and No. 281 had an acid reaction, even after boiling.

Effluents.

Four samples of percolation effluent from the sewage treated *once* on the peat land were examined (three of these in duplicate after incubation), and one sample—No. 287—(in duplicate) from the gravelly portion of the farm. Of the peat land effluents, No. 278 was very bad. When analysed, it was a canary yellow and turbid liquid smelling of sulphuretted hydrogen; it contained much ferrous iron, and the colour of the liquid was mostly due to that iron, though partly also to the peaty matter in solution. Nos. 280 and 282 were also bad; the first of these was dark brown in colour but nearly clear, while the second contained much black suspended solid matter. There was not much lime in these effluents (Nos. 278 and 282 were tested for this); the addition of lime to the land would therefore probably improve matters somewhat. No. 286 (from peat) and No. 287 (from gravelly soil) were drawn with the intention that they should be comparative samples of effluent from the same sewage, but the respective amounts of chlorine present in them showed that this was not really the case. No. 286 was decidedly better than the other peat land effluents and practically withstood incubation for five days, though it could not

be called good, while No. 287 contained some nitrate and remained sweet through the incubation test, though in the duplicate sample incubated for 13 days the nitrate was altogether exhausted after incubation; unfortunately the analysis of this last sample (No. 287) was discordant as regards the figures for total nitrogen, nitric nitrogen and organic nitrogen. Thus all the four effluents from peat land were bad or nearly so, while the one from gravel was better, though not by any means of high quality.

Water from Unsewaged Peat Land.

Three samples—Nos. 279, 283 and 290—were examined, two of them in duplicate after incubation. Judging from the comparatively small proportion of chlorine in these, at least in Nos. 279 and 290, the samples were evidently peat water without sewage contamination, in accordance with the opinion arrived at both by the Manager of the farm and by Mr. Kershaw (*see* Mr. Kershaw's "Notes on Samples" *). They contained, of course, a good deal of oxidizable organic matter, as measured by the "oxygen absorbed" test, and also appreciable amounts of unoxidized nitrogen. There was very little lime present in them, and it will be observed (*see* Tables of Analysis) that they remained acid after being boiled. All of them kept sweet upon incubation, excepting the duplicate of No. 283, which was strongly putrid after being incubated for twelve days; this is another instance of a sample keeping sweet after six days' incubation at 26·7° C. (80° F.), but failing to withstand incubation for 12 days.

The Parrin Brook; Water above and below effluent outfall.

Four samples were examined. Of these Nos. 284 and 288 were taken above the Worsley Farm effluent outfall, while Nos. 280A and 289 were drawn below it; Nos. 288 and 289 were corresponding samples, *i.e.*, drawn within ten minutes of one another. No. 284 kept sweet on incubation but was not satisfactory for a brook water, containing as it did little more than a trace of dissolved oxygen when analysed; the other three samples were badly contaminated. In all four there were present large amounts of suspended matter. As stated by Mr. Kershaw, however, in his "Notes on Samples," * this contamination is not due to the Worsley Farm alone, but also to another sewage farm which discharges its effluent into the stream higher up. If the figures of analysis in Nos. 288 and 289—corresponding samples, one drawn above the Worsley effluent outfall and the other below it—are referred to, it will be seen that this contention is borne out. Both samples were bad, but the one drawn above the effluent outfall was slightly worse than the other.

---

* Part IV.: Engineering and Practical Report.

WORSLEY SEWAGE FARM, 1901.

TABLES OF ANALYSIS.

INDEX.

	PAGE
Sewages and Effluents, Nos. 277, 278, 280, 281	270
„ „ Nos. 282, 285, 286, 287	271
Water from Peat Land Nos. 279, 283, 290	272
Brook water above and below Effluent Outfall Nos. 280A, 284, 288, 289	273

WORSLEY SEWAGE FARM, 1901.

Sewages and Effluents.

No. of Sample	277	278	278	280	281
Nature of Sample	Crude Sewage (dark-coloured when drawn).	Final Effluent (yellow-coloured), off pure bog peat. Only corresponds approximately to No. 277.	Small Duplicate.	Effluent from Peat Land (yellow when drawn).	Crude Sewag (contained some dye liquor
Drawn	Monday, 13th May 1901, 11.45 a.m.	Monday, 13th May 1901, 12.15 noon.	—	Wednesday, 15th May 1901, 12.15 noon.	Monday, 20th M 1901, 4.15 p.m.
Temperature of sample	13·3° C. (56° F.)	8·9° C. (48° F.)	—	10·0° C. (50° F.)	13·3 C. (56° F.
Temperature of air	10·0° C. (50° F.)	15·6° C. (60° F.)	—	18·9° C. (66° F.)	21·1° C. (70° F.
If jointed or incubated	—	—	Jointed and incubated 14th May, when it was already greenish black.	—	—
Analysed	14th May 1901.	14th May 1901.	Opened 17th May 1901.	16th May 1901.	22nd May 1901
Parts per 100,000, *by weight.*					
Ammoniacal nitrogen (a) by direct Nesslerization.	3·72 (approx. (slightly turbid).	—	—	—	Not done.
Ammoniacal nitrogen (b) by distillation.	3·07	0·80 (Probably too high, because of sulphides.	—	(?) 1·12 (Evidently too high, from sulphide present.	2·71 (Probabl a littl high.
Albuminoid nitrogen	1·62	0·14	—	0·23	1·37
Nitrous nitrogen	None.	None or trace.	—	None.	None.
Nitric nitrogen	Not done.	Not done.	—	Not done.	Not done.
Total nitrogen, by Kjeldahl, *with* reduction.	6·19	(a) 0·88 (b) 0·87	—	1·17	5·73
Blank	(0·22 in 4·71)	(0·33 in 1·77 and in 1·75).	—	(0·33 in 2·24)	(0·33 in 5·01)
"X" nitrogen	1·50	?	—	?	1·65
Organic nitrogen, by Kjeldahl, *with* reduction.	3·12	?	—	?	3·02
Organic nitrogen, by Kjeldahl, *without* reduction: Taking ammonia by distillation	—	—	—	—	—
Oxygen absorbed from permanganate at 26·7° C. (80° F.); *at once.*	6·28	1·27	—	1·74	10·49
,, ,, ,, *after four hours*	22·44	3·59	—	4·58	31·28
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once*	—	—	—	—	—
,, ,, ,, *after four hours*	—	—	—	—	—
Smell after incubation	—	—	—	—	—
Chlorine	12·60	8·42	—	8·96	21·98
Parts per 100,000, *by volume.*					
Solids by centrifuge	485·0 (3 minutes).	—	—	2·0 (1 minute).	284·0 (2 minutes).
Gases: parts per 1 000, *by volume.*					
Oxygen (by cuprous chloride) when sample was analysed	—	—	—	—	—
Remarks	Very considerable *black* sediment, along with dark brown and greyish fibrous particles. Slight sewage smell. Alkaline. *N.B.*—This sewage contained dye refuse.	Canary yellow and turbid liquid, with a smell of sulphuretted hydrogen. Not a great deal of lime in solution. (The soil evidently needs lime.) Considerable amount of sulphate. Much ferrous iron. The reaction was slightly acid in the cold, alkaline on boiling. When boiled, much sulphuretted hydrogen was evolved. The colour of this effluent was due mostly to the iron present in it, but partly also to the peaty matter.	Black. Strong odour of sulphides. Not analysed.	Very dark brown and slightly turbid liquid. Very little sediment. Strong smell of sulphuretted hydrogen. Distinctly acid in the cold, alkaline on boiling.	Dark grey and very turbid liquid. Soapy smell. Considerable amount of practically black sediment. Reaction acid, *even on boiling*, but not very acid.

WORSLEY SEWAGE FARM, 1901.

Sewages and Effluents.

282	282	285	286	286	287	287
UENT FROM AT LAND ow, with a ge and iron smell).	SMALL DUPLICATE.	CRUDE SEWAGE (contained dye refuse).	EFFLUENT FROM PEAT LAND, corresponding to Sewage No. 285.	SMALL DUPLICATE.	EFFLUENT FROM GRAVEL SOIL, corresponding to Sewage No. 285.	SMALL DUPLICATE.
ay, 20th May, , 5.30 p.m.	—	Tuesday, 28th May 1901, 12.0 noon.	Tuesday, 28th May 1901, 1.20 p.m.	—	Tuesday, 28th May 1901, 1 p.m.	—
° C. (57° F.)	—	15·6° C. (60° F.)	15·6° C. (60° F.)	—	14·4° C. (58° F.)	—
° C. (69° F.)	—	23·3° C. (74° F.)	23·9° C. (75° F.)	—	25·6° C. (78° F.)	—
—	Jointed and incubated, 22nd May.	—	—	Jointed and incubated, 29th May.	—	Jointed and incubated, 29th May.
May 1901.	Opened 23rd May 1901.	29th May 1901.	29th May 1901.	11th June 1901.	29th May 1901.	11th June 1901.
one, because sulphuretted ogen present.	—	—	—	—	—	—
7 { Na_2CO_3, *aq.* added.	—	2·28 { 7 drops, Na_2CO_3, *aq.* added.	0·66	0·68 { 6 drops, Na_2CO_3, *aq.*	0·45	0·42
0·16	—	1·20	0·10	0·06	0·10	0·07
None.	—	None.	None, or trace	None.	None.	None.
Not done.	—	Not done.	0·03	None.	0·62 (?)	None.
0·86	—	4·24	1·04	—	(a) 0·51 (b) 0·66	—
22 in 1·47)	—	(0·22 in 6·36)	(0·33 in 2·02)	—	(0·33 in 1·16 ; 0·34 in 1·42).	—
None (?)	—	0·76	0·25	—	?	—
0·16 (?)	—	1·96	0·35	—	0·10 (?)	—
0·13 (?)	—	—	—	—	—	—
1·44	—	7·84	1·12	1·87	0·71	0·73
4·22	—	23·14	3·31	—	2·35	—
·90 } Seven days.	—	—	1·08	—	0·59	
·71 }	—	—	2·71	—	2·09	—
of sulphides. ple was black e incubation).	—	—	Smell very strong, but not putrid. No nitrite.	Putrid.	Sweet ; trace of nitrite.	Sweet.
8·70	—	25·00	7·80	—	11·74	—
70·0 minute).	—	235·0 (1 minute).	About 5·0	—	10·0 approx.	—
—	—	—	None.	—	None.	—
ample looked k and smelt sulphuretted rogen. It was lescent and ow when filed. Considerable black deposit. Slightly acid the cold ; htly alkaline oiling.	Black and smelling of sulphuretted hydrogen. Inclining to acid in the cold, alkaline on boiling. Not analysed.	This sample contained a large amount of black sediment. The liquid was brown when filtered. Almost neutral, though tending to alkaline. Strong smell of ammonium sulphide.	Brown, practically clear liquid, with hardly any sediment. No smell. Alkaline. The above sample is evidently just within the border line.	After incubation this sample was slightly turbid and brownish, but less so than No. 287. Hardly any sediment. Distinctly putrid and smelling of sulphuretted hydrogen, but not black. Alkaline, especially on boiling.	Liquid very brown —more so than No. 286. Some sediment aggregated into light-brown lumps. Clean smell; alkaline on boiling. *Note.*—There is of course an error in one of the nitrogen figures of the above analysis, most likely in the nitrate.	After incubation this liquid was very yellow or light brown. Practically no smell ; alkaline, especially on boiling. This sample is therefore much better than No. 286 (from peat land).
lution there was a small amount ime, a somewhat small amount ulphate, and a large amount of ous iron.						

WORSLEY SEWAGE FARM, 1901.

Water from Peat Land.

No. of Sample	279	279	283	283	290
Nature of Sample	Liquor from Peat Land (not effluent) yellowish in colour.	Small Duplicate.	Peat Water (not effluent) yellow in colour.	Small Duplicate.	Peat Water (dirty coloured).
Drawn	Wednesday, 15th May 1901, 12 noon.	—	Monday, 20th May 1901, 4.25 p.m.	—	Tuesday, 28th May 1901, 12.15 noon.
Temperature of sample	12·2° C. (54° F.)	—	15·6° C. (60° F.)	—	16·1° C. (61° F.)
Temperature of air	18·3° C. (65° F.)	—	21·1° C. (70° F.)	—	24·4° C. (76° F.)
If jointed or incubated	—	Jointed and incubated, 16th May.	—	Jointed and incubated, 22nd May.	—
Analysed	17th May 1901.	Opened, 31st May 1901.	22nd May 1901.	Opened, 3rd July 1901.	29th May 1901.
Parts per 100,000, *by weight.*					
Ammoniacal nitrogen (a) by direct Nesslerization.	—	—	—	—	—
Ammoniacal nitrogen (b) by distillation	0·027 { Na_2CO_3 *aq.* added.	—	0·097	—	0·06 { 6 drops Na_2CO_3 *aq.* added.
Albuminoid nitrogen	0·075	—	0·106	—	0·08
Nitrous "	None.	—	None.	—	None.
Nitric "	0·008	—	None.	—	None.
Total nitrogen, by Kjeldahl, *with* reduction.	0·179	—	0·301	—	0·28
Blank	(0·22 in 0·48)	—	(0·33 in 0·82)	—	(0·22 in 0·62)
"X" nitrogen	0·069	—	0·098	—	0·14
Organic nitrogen, by Kjeldahl, *with* reduction.	0·144	—	0·204	—	0·22
Organic nitrogen, by Kjeldahl, *without* reduction: Taking ammonia by distillation	0·137	—	—	—	0·12
Oxygen absorbed from permanganate at 26·7° C. (80 F.); *at once.*	0·56	—	0·55	—	0·62
" " " *after four hours*	2·57	—	1·41	—	2·79
Oxygen absorbed from permanganate by sample incubated for five days at 26·7° C. (80° F.); *at once*	0·44	—	0·67 } Six days.	—	0·69
" " " *after four hours*	2·47	—	2·50 } Six days.	—	2·76
Smell after incubation	Strong earthy. No nitrite.	—	Earthy. No nitrite, or trace only.	—	Earthy. No nitrite.
Chlorine	1·20	—	2·60	—	1·22
Parts per 100,000, *by volume.*					
Solids, by centrifuge	59·0 (1 minute.)	—	16·4 (2 minutes.)	—	35·0 (1 minute.)
Gases: parts per 1,000, *by volume.*					
*Oxygen (by cuprous chloride) when sample was analysed.	About 3·5 (Very green to read.)	Trace, say 0·25	About 1·0 (Very green.)	—	2·5 { Two observers.
Remarks	This liquid was yellowish, even when filtered. Very considerable amount of dark-brown sediment. Distinctly acid, and more so after boiling. Earthy smell. Very little lime. Very appreciable amount of sulphate. Small amount of ferrous iron. *Note.*—This peat land was on the sewage farm.	This sample (brown-coloured) smelt quite sweet after incubation; any slight smell was more earthy than peaty. Strongly acid in the cold.	Brownish, but fairly clear liquid. Some brown sediment. Peaty smell. Nearly neutral, perhaps slightly acid in the cold, and the same on boiling. *Note.*—This sample, like No. 279, was also from peat land on the farm.	After incubation this sample was putrid, smelling strongly of sulphides. It was not analysed.	Liquid yellow, with considerable dark-brown and black sediment. Strong earthy smell. Acid even after boiling. Very little lime. Very considerable amount of sulphate. Very little ferrous iron. *Note.*—This water was from land on the farm.

**Note.*—The yellow or brown colour of these waters would make the readings of the dissolved oxygen by the copper chloride method too low.

WORSLEY SEWAGE FARM, 1901.

Brook Waters.

280a	284	288	289
Brook Water containing effluent, drawn 20 yards below outfall (muddy when drawn).	Brook Water above effluent outfall (muddy coloured).	Brook Water above effluent outfall (opalescent).	Brook Water (opalescent) drawn 150 yards below effluent outfall.
Wednesday, 15th May 1901, 12.45 noon.	Monday, 20th May 1901, 4.45 p.m.	Tuesday, 28th May 1901, 12.35 noon.	Tuesday, 28th May 1901, 12.45 noon.
11·7° C. (53° F.)	15·0° C. (59° F.)	17·8° C. (64° F.)	17·8° C. (64° F·)
19·7° C. (61° F.)	21·1° C. (70° F.)	26·7° C. (80° F.)	26·7° C. (80° F.)
—	—	—	—
16th May 1901.	2nd May 1901.	30th May 1901.	30th May 1901.
Turbid.	Turbid.	Turbid.	—
0·50	0·59	0·70 { 2 drops Na_2CO_3 *aq.* added.	0·73
0·09	0·09	0·12	0·09
None.	None.	None.	None.
0·08	0·13	0·02	Not done.
0·78	0·87	0·92	0·91
(0·22 in 1·35)	(0·22 in 1·48)	(0·22 in 1·56)	(0·33 in 1·49)
0·11	0·06	0·08	0·09
0·20	0·15	0·20	0·18
0·26	0·18	0·20	—
0·49	0·16	0·33	0·14
1·58	0·81	1·43	1·26
0·72	0·06 } Seven days.	0·76	0·90
1·49	0·67 } Seven days.	1·70	1·50
Putrid; black. Sulphide smell.	Earthy; sweet. No nitrite.	Putrid; black. Smell of sulphides.	Strongly putrid.
29·28	36·30	39·6	33·8
16·0 (1 minute.)	11·0 (1 minute.)	12·3 (1 minute.)	27·0 (1 minute.)
None.	About 0·5 { Two observers. }	None.	—
Liquid yellow, even when filtered. Distinct sewage smell on warming. Lime, very considerable. Sulphate, very much. Ferrous iron, none. Ferric iron, moderate amount.	This water had a slight brown tinge, and was a trifle opalescent. Rather considerable amount of aggregated dark brown sediment (much for a brook water). Earthy smell. Faintly alkaline. Lime, considerable amount. Sulphate, very large amount. Ferrous iron, probably a little. Ferric iron, none.	Opalescent; contained much sediment for a brook water. Slightly yellow when filtered. Sewage smell with trace of sulphide smell. Lime, very considerable. Sulphate, a great deal. Ferrous iron, small amount. Even next day (31st May) with the bottle half empty, the smell was putrid.	Opalescent, slightly yellow liquid. Sediment was brownish-grey. Sewage smell. Alkaline.

Mechanical Analysis of Soils and Subsoils, together with deductions drawn from this.

By G. McGowan and R. S. Finlow.

As was recognised thirty years ago by the Rivers Pollution Commission, the purification of sewage by filtration through a soil depends largely upon the physical structure of the latter, as well as upon its depth. It was therefore thought advisable to make a careful mechanical analysis of the soils of those sewage farms which have been under prolonged observation. In the case of stiff clay soils, through which little filtration can take place, a mechanical analysis has, of course, less value than in the case of porous soils.

Some of the main points in connection with the filtration of water through soil are admirably summarized by Whitney in the *U.S. Weather Bureau Bulletin, No.* 4, as follows :—

"The circulation of water in the soil is due to gravity, or the weight of water, acting with a constant force to pull the water downward, and also to surface tension, or the contracting power of the free surface of water (water-air surface), which tends to move the water either up or down, or in any direction, according to circumstances. There is a large amount of space between the grains in all soils in which water may be held, ranging from about thirty per cent. in light sandy lands to sixty-five or seventy per cent. in stiff clay soils. The relative rate of movement of water through a given depth of soil will depend upon how much space there is in the soil; upon how much this space is divided up, *i.e.*, upon how many grains (particles) there are per unit volume of soil; upon the arrangement of the grains of sand and clay; and upon how this skeleton structure is filled in and modified with organic matter. It also appears that the ordinary manures and fertilizers change this surface tension or pulling power of water; that they also change the arrangement of the grains, and consequently the texture or structure of the soil may be changed and the relation of the soil to water, through the effect of the ordinary manures and fertilizers in causing flocculation or the reverse."

The volume occupied by any given weight of a soil is only partly filled up by solid particles, there being small air spaces between these. Owing, however, to the vastly greater number of particles in heavy soils, their individual air-spaces are very much smaller than the individual air-spaces of a sandy or a gravelly soil. Filtration therefore proceeds with much greater difficulty in the case of clay, owing to increased friction. It can of course be seen at a glance that, in a given volume of a coarse gravelly or sandy soil, there must be a smaller number of particles than in an equal volume of a light loam, and similarly it is evident that a light loam contains fewer particles than a heavy loam or a clay. Experience has proved that a light loam gives better results, as regards sewage purification, than either sand on the one hand or heavy soil on the other, but it was with the hope of finding a more or less definite relation between the number and size of the particles in a soil and the purifying powers of that soil that this investigation was undertaken; or, to put it differently, one object of this investigation was to attempt to find an approximate limit—as regards efficient filtration of sewage—for the number of particles permissible in unit volume of a soil. The main object was to see whether the mechanical analysis of a soil and subsoil would afford data of a sufficiently definite character to allow of an approximate calculation being made as to the amount of sewage which that soil and subsoil would purify.

The Taking of Samples of Soil for Analysis.

The correct sampling of a soil or subsoil for analysis is obviously of fundamental importance, as all the other results depend upon it. How this was done on the different farms is described in the Engineering Report,* but it may be shortly abstracted here :—

Six small tins were used for each sample of soil and six for each subsoil. Further, each tin of soil contained three approximately equal portions drawn from different parts of fields within the irrigable area of the respective farm, those fields of course not being under sewage at the time. The whole sample, which weighed about 3 kilos. (7 lbs.), thus consisted of eighteen separate typical portions, and it represented the soil (*a*) actually at the surface and (*b*) at about the middle of its depth.

The subsoils were sampled in the same way as the soils, but each tin contained only two portions. The respective depths at which the latter were taken were (*a*) 12 inches and (*b*) 18 inches below the base of the soil.

Sub-sampling in the Laboratory.

On receipt of the samples at the laboratory, they were spread out on paper on the floor of an empty room, in which there was a free circulation of air, being merely protected from dust. Here they were allowed to remain until "air-dry," the time given being one month and upwards.

When required for analysis, the following method of subsampling was employed: —The whole sample after careful mixing and cautious crushing of lumps, care being taken not to break brittle stones, etc., was divided into four parts; two opposite segments were mixed and the process of subdivision repeated. This first subsample having been weighed, any large stones and gravel, after being rubbed with the finger to remove fine earth, were taken out and weighed also, the detached soil being added to the rest of the finer matter. This latter was then divided again, if necessary, and suitable weights were taken for analysis. The proportion of stones added to the earth in this final small subsample was calculated from their relative weight in the large subsample.

The following example will serve to illustrate the foregoing :—

	grams
Weight of first subsample (stones and earth) - - - -	= 651·6
Weight of stones and gravel - - - - - - - - -	= 144·1
∴ Weight of earth - - - - - - - - - - -	= 507·5
Weight of earth in final subsample - - - - - - - -	= 30·0

By proportion :—

507·5 : 144·1 = 30 : x, where x is the proportion of stones for 30 grams earth. Therefore $x = 8·52$ grams.

Thus, total "air-dry" weight of final subsample = 38·52 grams.

The sample of air-dried soil for analysis having been thus prepared, a determination of moisture was made by drying another portion—obtained in the same way—at about 110° C., cooling and weighing; the loss of weight being taken as moisture. The "dry" weight of the sample for analysis was calculated from this. The loss on ignition, which includes organic matter, combined water, etc., was then estimated in the dry residue from the moisture determination.

Method of Mechanical Analysis.

The method employed was essentially that of Osborne, which is one of sieving and "beaker elutriation." (*Connecticut Agricultural Experiment Station Annual Report* 1886, *pp.* 141 *et seq.*; also Wiley, "*Principles and Practice of Agricultural Analysis,*" *Vol. I., p.* 196.)

The following is a detailed description :—

Sieving:—The sieves, the holes in which were circular, had mesh diameters of 2·0 m.m., 1·0 m.m., 0·5 m.m., and 0·25 m.m. respectively.

A weighed portion of, say, 15–40 grams. of the subsample of soil was first soaked in water for a short time and then passed through the sieves in the descending order of their mesh diameters, this process being aided by gentle rubbing with the finger and by a slow stream of water from a wash bottle. The undersurface of the finest sieve was wetted before commencing, The several portions retained by the sieves were then collected separately, dried at 110°, and weighed.

* Part IV.: Engineering and Practical Report.

Elutriation.—By this process the particles which have passed through the finest sieve are separated into four grades, the limits of size of which are :—

(*a*) 0·25 m.m. to 0·05 m.m. diameter, called "sand."

(*b*) 0·05 m.m. to 0·01 m.m. diameter, called "silt."

(*c*) 0·01 m.m. and below, which settles through about 9 inches of water in 24 hours, called "dust."

(*d*) The residue remaining in suspension in the water after the dust has settled, called "clay."

The measurements refer to particles of colourless crystalline matter, mainly silica, non-crystalline matter being neglected.

These last four grades are obtained in the following manner by means of a series of fractional subsidences from water, the freedom or otherwise of the sediments from particles above or below any pair of the foregoing limits being ascertained by means of the microscope and scale.

The turbid liquid from the sieving is allowed to stand for, say, ten minutes, in order that the coarser particles—sand and silt—may settle as completely as possible. It is then decanted from this first sediment and allowed to stand for a further period of ten minutes. If, after again decanting, this second sediment is free from sand and silt, the liquid, which we may call A, is set aside. The various sediments from these decantations, which contain all the sand and silt together with some dust and clay, are now mixed and gently rubbed, either with the finger or with a rubber pestle, to break up aggregates of dust and clay; water is then added and the whole is vigorously agitated with a rubber-tipped rod, so as to get all the solid matter into temporary suspension. After standing for a minute or two the turbid liquid is decanted, the whole process being repeated time after time with the sediment until, on standing for about one minute, the supernatant liquid is seen to be quite clear. The sediment (S), is then, as a rule, free from dust and clay, but the microscope must of course decide this question.

Having ascertained that the several decanted liquids contain no particles larger than dust, these are mixed with liquid A in a vessel about nine inches high, and the whole is thoroughly stirred and allowed to stand for 24 hours. The turbid liquid B is then siphoned off, and the sediment, dried at 110° C., is weighed as dust. B is now treated with 3 c.c. per litre of nitric acid and set aside, for several days if necessary, until the whole of the matter in suspension has settled. The clear liquid, which usually amounts to 5–10 litres, is then siphoned off and thrown away, while the sediment is dried at 110° C. and weighed as clay.*

The sand and silt in sediment S are also separated by successive subsidences and decantations, the times of subsidence being suitably adjusted. When no more silt can be easily removed without decanting sand as well, the decantation is done into a second vessel, and the subsidences timed so as to remove as much silt as possible. In this way, with care, three-quarters of the sand is obtained free from silt. The mixed silt and sand in the second vessel are then treated again in the same way. It is obviously impossible to make a complete separation, but, by a sufficient number of decantations, the weight of the mixed fraction becomes very small, and then the fraction can be divided equally between the "sand" and the "silt." The separate fractions are lastly dried at 110°C. and weighed.

The remarks in the last paragraph apply equally of course to the separation of any two fractions.

It will be found in practice that the work of separating the various fractions, as above described, is laborious. This is especially the case with heavy soils, where the aggregates of clay and dust cause great difficulty by subsiding along with sand or silt. Of course, if the clay aggregates are not broken up, the result is inaccurate, the tendency being for sand and silt to be too high at the expense of dust and clay.

Two remedies have been proposed for this. The first one is that the soil should be boiled for a long time—up to 36 hours—before commencing elutriation. This was found to shorten the process considerably; but the boiling is said to break up the "sand" particles to some extent, and thus to raise artificially the percentages of the finer fractions, Two analyses of the Leicester soil—boiled and unboiled before elutriation—are given for purposes of comparison. It will be seen in Table A, however, that in this case the differences in the finest fractions are not very great. The other remedy, which seems more reasonable, is to add a little ammonia to the elutriating water. The ammonia breaks up the aggregates in virtue of its tendency to bring "clay" into the colloid form. Unfortunately, time did not allow of our trying this.

---

* The nitric acid of course dissolves any lime present in the "clay" fraction, and hence it would be necessary to substitute some salt for this acid as a precipitant, if calcareous soils were being examined.

The following Table A gives the percentage figures of the mechanical analysis of eight soils and four subsoils, carried out as has just been described. They are :—

Nottingham Farm soil and subsoil.

Cambridge Farm soil and subsoil.

Croydon (Beddington) Farm soil and subsoil.

Aldershot Camp Farm soil and subsoil.

Altrincham Farm soil.

Rugby Farm soil.

Leicester Farm soil.

South Norwood Farm soil.

Two series of results—"ignited" and "unignited"—are given in this table. The "unignited" results were arrived at by drying at 110°C. the fractions obtained by sieving and elutriation, and calculating the percentages on the original weight of soil taken, dried at 110°C. The "ignited" results were obtained by igniting the fractions, or suitable portions of them, after drying at 110°C., and calculating the percentages of the residues on the original weight of dry soil.

A separate determination of the loss on ignition, made in a fresh sample, will be seen in most cases to agree substantially with the sum of the losses sustained on ignition by the various fractions taken together.

No further explanation of this table is necessary here, as Tables C and D, which are derived from it, are discussed in detail later on ; but a very casual examination of it will shew how widely the various types of soil differ in their mechanical composition.

With regard to the fractions of "dust" and "clay," it must of course be remembered that the diameters assigned to their particles cannot be taken as exact. Still, various workers, after careful observations, have come to the conclusion that the values given to them are approximately correct.

Brief Description of the Soils and Subsoils analysed.

Aldershot. Surface soil is a shallow sand, 6 inches to 10 inches deep. Subsoil is also sand, but mixed with reddish friable matter of an exceedingly fine texture, a little gravel occurring in parts. There were also small aggregates of very fine iron-green coloured material. Drains 3 feet 3 inches deep on the average.

Cambridge. Soil is a sandy loam 12 inches to 15 inches deep, overlying a compact stratum of gravel and sand, 6 to 10 feet deep, Gault clay below. Drains 3 feet 6 inches to 6 feet deep.

Nottingham. Soil is a light loam 7 inches to 15 inches deep, while the subsoil is coarse river gravel. Drains, 6 feet to 10 feet deep.

Beddington. Light loamy soil 12 inches to 18 inches deep. Subsoil is gravel and sand 6 feet to 12 feet deep. Where there are drains, these are 4 feet to 9 feet deep.

Altrincham. Black porous soil of decomposed peat mixed with sand, overlying fine white sand and gravel. Drains, 3 feet 9 inches deep.

Rugby. Heavy loam 10 inches deep over yellow clay, but pot-holes of gravel occur in places.

Leicester. Stiff clayey soil overlying dense clay.

South Norwood. Clayey soil, somewhat "lightened" artificially, overlying stiff clay.

TABLE A.

RESULTS OF MECHANICAL ANALYSES GIVEN IN PERCENTAGES.

TABLE A.

RESULTS OF MECHANICAL ANALYSES GIVEN IN PERCENTAGES.

(1.) Surface Soils.

Name of Fraction.	Nottingham. Percentages. Not Ignited.	Nottingham. Ignited.	Nottingham. Differences.	Cambridge. Percentages. Not Ignited.	Cambridge. Ignited.	Cambridge. Differences.
"Gravel" - - - Mean diameter = 1·0 c.m.	—	—	—	—	—	—
Fine "gravel" - - ,, ,, = 0·35	17·20	16·67	0·53	—	—	—
Fine "gravel" - - ,, ,, = 0·25	—	—	—	4·84	4·70	0·14
Coarse "sand" - ,, ,, = 0·15	1·88	1·59	0·29	1·59	1·46	0·13
Coarse "sand" - ,, ,, = 0·075	1·44	1·31	0·13	1·80	1·68	0·12
Medium "sand" - - ,, ,, = 0·0375	3·54	3·44	0·10	4·03	3·92	0·11
"Sand" - - - - ,, ,, = 0·015	45·14	44·24	0·90	60·31	59·14	1·17
"Silt" - - - - ,, ,, = 0·003	17·00	15·42	1·58	17·63	15·85	1·78
"Dust," *i.e.*, below 0·001 c.m. diameter, which settles from water in 24 hours - - ,, ,, = 0·00075	11·16	8·89	2·27	6·90	5·94	0·96
"Clay," *i.e.*, the residue in suspension which is precipitated by dilute nitric acid - ,, ,, = 0·000255	1·74	1·44	0·30	1·36	1·12	0·24
Loss on ignition, determined in a separate sample of soil, as described above - - - - - - -	—	6·16	—	—	5·00	—
Totals - - -	99·10	99·16	6·10	98·46	98·81	4·65

(2.) Subsoils.

Name of Fraction.	Nottingham. Percentages. Not Ignited.	Nottingham. Ignited.	Nottingham. Differences.	Cambridge. Percentages. Not Ignited.	Cambridge. Ignited.	Cambridge. Differences.
"Gravel" - - - Mean diameter = 1·0 c.m.	25·47	25·47	—	—	—	—
Fine "gravel" - - ,, ,, = 0·35	14·99	14·65	0·34	20·87	20·87	—
Fine "gravel" - - ,, ,, = 0·25	0·00	0·00	—	19·40	18·87	0·53
Coarse "sand" - ,, ,, = 0·15	2·98	2·93	0·05	4·18	4·06	0·12
Coarse "sand" - ,, ,, = 0·075	3·00	2·94	0·06	4·26	4·13	0·13
Medium "sand" - - ,, ,, = 0·0375	8·22	8·16	0·06	7·82	7·70	0·12
"Sand" - - - - ,, ,, = 0·015	40·14	39·88	0·26	38·83	38·46	0·37
"Silt" - - - - ,, ,, = 0·003	1·89	1·80	0·09	2·14	1·96	0·18
"Dust," *i.e.*, below 0·001 c.m. diameter, which settles from water in 24 hours - - ,, ,, = 0·00075	1·85	1·63	0·22	1·26	1·03	0·23
"Clay," *i.e.*, the residue in suspension which is precipitated by dilute nitric acid - ,, ,, = 0·000255	0·67	0·60	0·07	0·41	0·35	0·06
Loss on ignition, determined in a separate sample of subsoil, as described above- - - - - - -	—	1·28	—	—	1·20	—
Totals - - -	99·21	99·34	1·15	99·17	98·63	1·74

TABLE A.

RESULTS OF MECHANICAL ANALYSES GIVEN IN PERCENTAGES.

(1.) Surface Soils.

Beddington.			Aldershot.			Altrincham.		
Percentages.			Percentages.			Percentages.		
Not Ignited.	Ignited.	Differences.	Not Ignited.	Ignited.	Differences.	Not Ignited.	Ignited.	Differences.
22·67	22·67	—	—	—	—	—	—	—
11·34	10·97	0·37	—	—	—	—	—	—
—	—	—	6·29	5·94	0·35	6·34	4·85	1·49
0·88	0·80	0·08	0·69	0·62	0·07	3·16	2·05	1·11
0·63	0·59	0·04	0·60	0·53	0·07	3·65	2·37	1·28
1·75	1·70	0·05	1·35	1·27	0·08	6·80	5·60	1·20
40·16	39·14	1·02	82·67	81·76	0·91	37·56	33·22	4·34
14·32	12·53	1·79	4·19	2·93	1·26	27·16	16·44	10·72
6·88	5·56	1·32	3·12	2·05	1·07	10·95	7·64	3·31
0·71	0·57	0·14	0·35	0·24	0·11	2·83	2·13	0·70
—	5·46	—	—	3·60	—	—	23·24	—
99·34	100·09	4·81	99·26	98·94	3·92	98·45	97·54	24·15

(2.) Subsoils.

Beddington.			Aldershot.		
Percentages.			Percentages.		
Not Ignited.	Ignited.	Differences.	Not Ignited.	Ignited.	Differences.
57·47	—	—	—	—	—
19·28	—	—	—	—	—
0·00	—	—	1·52	1·50	0·02
2·01	—	—	0·90	0·87	0·03
1·14	—	—	0·45	0·44	0·01
2·56	—	—	1·29	1·28	0·01
14·16	—	—	80·13	79·50	0·63
0·98	—	—	6·58	6·21	0·37
2·48	—	—	5·52	5·13	0·39
0·25	—	—	2·62	2·28	0·34
—	—	—	—	1·80	—
100·33	—	—	99·01	99·01	1·80

TABLE A—*continued.*

RESULTS OF MECHANICAL ANALYSES GIVEN IN PERCENTAGES—*continued.*

(1.) SURFACE SOILS.

Name of Fraction.	Rugby. Percentages. Not Ignited.	Rugby. Percentages. Ignited.	Rugby. Percentages. Differences.	Leicester (not boiled). Percentages. Not Ignited.	Leicester (not boiled). Percentages. Ignited	Leicester (not boiled). Percentages. Differences.
"Gravel" - - - Mean diameter = 1·0 c.m.	—	—	—	—	—	—
Fine "gravel" - - " " = 0·35	—	—	—	—	—	—
Fine "gravel" - - " " = 0·25	3·31	3·17	0·14	5·66	4·63	1·03
Coarse "sand" - " " = 0·15	1·13	1·04	0·09	2·38	1·81	0·57
Coarse "sand" - " " = 0·075	1·18	1·13	0·05	1·28	0·97	0·31
Medium "sand" - - " " = 0·0375	2·06	1·96	0·10	2·28	1·72	0·56
"Sand" - - - - " " = 0·015	36·74	35·91	1·83	37·02	34·16	2·86
Silt" - - - - " " = 0·003	25·51	21·88	3·63	35·23	29·75	5·48
"Dust," *i.e.*, below 0·001 c.m. diameter, which settles from water in 24 hours - - - " " = 0·00075	21·44	18·29	3·15	10·98	9·30	1·68
"Clay," *i.e.*, the residue in suspension which is precipitated by dilute nitric acid - " " = 0·000255	7·40	6·46	0·94	4·61	3·88	0·73
Loss on ignition, determined in a separate sample of soil, as described above - - - - - - -	—	9·24	—	—	11·52	—
TOTALS - - -	98·77	99·08	8·93	99·44	97·74	13·22

TABLE A—*continued.*

RESULTS OF MECHANICAL ANALYSES GIVEN IN PERCENTAGES—*continued.*

(1.) SURFACE SOILS.

LEICESTER (boiled).			SOUTH NORWOOD.		
Percentages.			Percentages.		
Not Ignited.	Ignited.	Differences.	Not Ignited.	Ignited.	Differences.
—	—	—	—	—	—
—	—	—	—	—	—
9·92	9·45	0·47	2·40	1·62	0·78
1·60	1·20	0·40	0·84	0·61	0·23
1·40	1·07	0·33	0·85	0·63	0·22
1·60	1·28	0·32	1·51	1·29	0·22
37·16	34·54	2·62	44·54	38·75	5·79
27·93	23·52	4·41	16·93	13·55	3·38
13·27	11·21	2·06	28·39	23·42	5·97
4·78	4·01	0·77	2·20	1·87	0·03
—	13·05	—	—	12·03	—
97·66	99·33	11·38	97·66	93·77	16·92

Real and Apparent Specific Gravities of Soils and Subsoils.

In order to complete the data for the calculations to be enumerated below, it was necessary to determine the "real" and "apparent" specific gravities and the real and apparent specific volumes of the various soils and subsoils. The purposes for which these determinations were required were :—

(*a*) The approximate estimation of the percentage air-space or "porosity";

(*b*) The approximate estimation of the numbers of particles (1) per gram and (2) per cubic centimetre of the soil or subsoil, and, depending on these :—

(*c*) The total surface area exposed by the particles per gram and per cubic centimetre of the soil and subsoil, respectively.

"Real" Specific Gravity and "Real" Specific Volume.

The "real" or true specific gravity is defined as the mass of a given volume of the soil compared with the mass of an equal volume of water. The "real" specific volume is defined as the volume of a given mass of the soil compared with that of an equal mass of water.

It will be seen from the above definitions that the "real" specific volume is the reciprocal of the "real" specific gravity, *i.e.* :—

$$\text{"real" specific volume} = \frac{1}{\text{"real" specific gravity.}}$$

If therefore either of these is determined, the other can be arrived at by calculation.

Determination of "Real" Specific Gravity.

The method employed was that of the specific gravity bottle, which is too well known to need description. It suffices to say, that in order to get rid of all air, the bottle containing the soil and water was warmed in a water bath and repeatedly shaken until no more bubbles were seen to come off.

Air-dried soil was used for these determinations, but it was afterwards found necessary to obtain values for the soil dried at 110°C. In making this calculation, therefore, the moisture was regarded as existing in the liquid form, and its weight and volume were subtracted from the weight and volume, respectively, of air-dried soil taken.

Samples of all the soils, excepting that of Aldershot Camp, which contained comparatively little organic or volatile matter, were ignited, and the real specific gravity of the residue determined by the same method. In the case of the Aldershot Camp soil and the various subsoils, the specific gravity of the material dried at 110°C. was taken as being sufficiently near the ignited value for the purposes of the calculations.

"Apparent" Specific Gravity and "Apparent" Specific Volume.

The interstitial spaces of all soils are filled with air or gas. If a volume V c.cs. of soil, including the air spaces, weighs m grams, then the ratio $\frac{m}{V}$ which gives the mass of one c.c. is defined as the "apparent" specific gravity of the soil. The reciprocal of this ratio, *i.e.*, $\frac{V}{m}$, which gives the volume of one gram, we have termed the "apparent" specific volume of the soil.

For the determination of these values, the air-dry friable soils were gently tapped down in a 500 c.c. cylinder, which was weighed before and after filling. The weight of the 500 c.cs. of soil was thus obtained, and the ratio of the weight to the volume gave the "apparent" specific gravity of the air-dry soil. The same calculation was employed as in the case of the real specific gravity to get the apparent specific gravity of the soil dried at 110°C. As the cylinder method was found inapplicable to heavy clay soils, their apparent specific gravities were arrived at approximately by measuring and then weighing a symmetrical block of the soil after drying it at 110° C. The ratio of the dry weight to the volume as obtained by measurement was taken as the apparent specific gravity. For example :—

Weight of dry block = 57·44 grams.

Dimensions of dry block = 4·5 × 4·4 × 2·15 c.m.

$$\therefore \text{Apparent specific gravity} = \frac{57{\cdot}44}{42{\cdot}57} = 1{\cdot}35.$$

$$\text{"Apparent" specific volume} = \frac{42{\cdot}57}{57{\cdot}44} = 0{\cdot}74.$$

Several determinations were made in each case, and the mean result was taken. The agreement between the results from separate blocks of the same soil or subsoil was on the whole fairly good.

Percentage Air Space or "Porosity."

The "porosity" was deduced from the two specific volumes in the following way:—

Let V_A be the apparent specific volume.
Let V_R be the real specific volume.

Then $V_A - V_R$ = air space

and, by proportion:—

$$\left.\begin{array}{r}\text{Percentage air space}\\ \text{or "porosity"}\end{array}\right\} = \frac{100\,(V_A - V_R)}{V_A}$$

Determination of Weight of Water held by a soil.

A column of the air-dry soil contained in a wide glass tube, perforated at its closed end with a few small holes, was first weighed and then thoroughly soaked with water from below upwards, in order that the air present might escape easily. It was then allowed to drain, being gently tapped from time to time, until no more drops of water came away, when its weight was again taken. From the difference between the weights of the dry and wet columns, the percentage weight of water retained was calculated.

The following Table B gives the results of the determination of—

a. The real and apparent specific gravities of the various soils and subsoils dried at 110° C.

b. The real specific gravity of all the ignited soils excepting that of Aldershot Camp.

c. The deduced "porosity" in all those cases where both real and apparent specific gravities were determined.

d. The weights of water held by 100 grams of the respective air-dried soils.

The last column of figures (*d*) is included in this table because the weight of water held by a soil must depend in part at least on the percentage of air space in that soil.

TABLE B.

Name of Farm.	Soil or Subsoil.	"Real" specific gravity of soil or sub-soil dried at 110° C.	"Real" specific gravity of the ignited soil or subsoil.	"Apparent" specific gravity of soil or sub-soil dried at 110° C.	Deduced "Porosity" or percentage air space.	Weight of water held by 100 grammes of the air-dry soil or subsoil (in grammes.)
Nottingham	Soil	2·566	2·720	1·442	43·8	32·5
Nottingham	Subsoil	2·695	Not done	1·773	34·2	20·1
Cambridge	Soil	2·603	2·726	1·434	44·9	30·3
Cambridge	Subsoil	2·631	Not done	1·821	30·8	14·3
Beddington	Soil	2·512	2·632	1·414	43·7	37·0
Beddington	Subsoil	2·490	Not done	1·843	26·0	10·5
Aldershot Camp	Soil	2·526	—	1·467	42·0	29·4
Aldershot Camp	Subsoil	2·579	—	1·469	43·0	28·8
Altrincham	Soil	2·377	2·946	0·858	63·9	71·5
Altrincham	Subsoil	—	—	—	—	—
Rugby	Soil	2·595	2·875	1·68	35·3	55·9
Rugby	Subsoil	—	—	1·622	—	—
Leicester	Soil	2·520	2·704	1·245	50·6	47·5
Leicester	Subsoil	—	—	1·796	—	—
South Norwood	Soil	2·308	2·722	1·223	47·1	64·3
South Norwood	Subsoil	—	—	1·884	—	—

It is noticeable in the foregoing table that the results for real specific gravity all lie practically between the limits 2·50 and 2·70, South Norwood and Altrincham being excepted. Those results, as will be seen later, are quite in accordance with conclusions arrived at from other independent data.

The "ignited" real specific gravities are also within fairly narrow limits.

The Altrincham figure, if compared with that for the unignited soil, at once corroborates the presence in the latter of the large percentage of organic or volatile matter of low specific gravity, which is shown in Table A.

These apparent specific gravities, though correct as far as we can judge, are not so concordant as might be wished. The results for Nottingham, Cambridge, and Beddington soils and subsoils are very close, but amongst the heavy soils there is some discrepancy. For instance, the figures for South Norwood and Leicester are, as would be expected, low; but that for Rugby, contrary to theory, is high. The value for Altrincham indicates the bulky nature of a peaty soil.

The "porosities" tend generally to shew, though not very satisfactorily, that very coarse material, such as the subsoil at Beddington, has less aggregate percentage air space than finer soils.

The results in the last column of the table, *i.e.*, weights of water held by 100 grams of the soils, also confirm the argument that the finer soils have a greater air space than the coarser ones.

Having obtained the percentage weights of the various fractions in a given soil and the real and apparent specific gravities of that soil, the next step was to deduce (1) The comparative number of particles in unit weight of the soil; (2) the surface exposed by the particles in unit weight; and (3) the aggregate filtration surface in the whole depth of soil and subsoil actually in use at a given farm.

Number of Particles in Unit Weight of Soil.

(1) To arrive at the comparative number of particles, several assumptions which are only partially justifiable have to be made, namely (a) that all the particles are spherical; (b) that they are arranged in the form of a "cubical lattice," *i.e.*, a block of cubes reduced to the inscribed spheres, the latter being supposed to retain their relative positions; (c) that no account is taken of the organic matter present. Thus, the results are not to be looked upon as representing accurately the absolute number of particles in unit weight of soil, "they only give approximate and comparative values for comparing one soil with another. The structure of the soil is altogether too intricate for us to expect ever to obtain absolute values" (Whitney, *loc. cit.*)

Opportunity may be taken at this point to express our admiration for the comprehensive and systematic work on the physics of soils which has been carried out by various American chemists, *e.g.*, Whitney, Wiley, Hilgard and Osborne.

The following table, C, gives the number of particles in one gramme of soil or subsoil, corresponding to the percentages in Table A.

In Table D are given the surface areas, in square centimetres, of the particles in 1 gramme of the soil or subsoil, these last figures being deduced from those in Table C.

In Table E are to be found comparative figures for the filtration surfaces: (1) in the whole depth of the soil; (2) in the whole depth of the subsoil down to the drains; (3) in the whole depth of soil and subsoil together down to the drains, all these being referred to the soil and subsoil of Nottingham as standards; only it must again be repeated here that, with regard to Beddington, this merely applies to about 100 acres, or one-quarter of the entire irrigable area, and not to the area used for surface irrigation.

TABLE C.

Number of Particles in one Gramme of Ignited Soil.

TABLE C.

Number of Particles in One Gramme of Ignited Soil.

Mean Diameter of Fraction in Centimetres.	Nottingham Soil.	Nottingham Subsoil.	Cambridge Soil.	Cambridge Subsoil.	Beddington Soil.	Beddington Subsoil.
1·0	—			—	—	—
0·35	3	—	—	4	2	3
0·25	—	—	2	9	—	—
0·15	4	6	3	9	2	5
0·075	23	50	30	73	11	21
0·0375	493	1,118	555	1,688	247	371
0·015	98,970	85,395	130,870	84,910	86,987	32,075
0·003	4,312,000	481,800	4,384,200	540,870	3,558,500	277,490
0·00075	159,100,000	27,922,000	105,147,000	18,191,000	101,060,000	44,941,000
0·000255	655,680,000	261,510,000	504,460,000	157,270,000	263,590,000	115,260,000
Totals - -	819,491,000	290,000,371	614,122,660	176,087,963	368,297,689	160,510,965

TABLE D.

Surface Area in Square Centimetres of the Particles in One Gramme of Ignited Soil.

Mean Diameter of Fraction in Centimetres.	Nottingham Soil.	Nottingham Subsoil.	Cambridge Soil.	Cambridge Subsoil.	Beddington Soil.	Beddington Subsoil.
1·0	—	0·58	—	—	0·55	1·38
0·35	1·13	0·95	—	1·40	0·76	1·32
0·25	0·00	0·00	0·44	1·77	0·00	0·00
0·15	0·25	0·44	0·23	0·63	0·13	0·32
0·075	0·41	0·89	0·53	1·29	0·19	0·37
0·0375	2·18	4·94	2·45	4·81	1·09	1·64
0·015	69·96	60·36	92·50	60·01	62·86	22·67
0·003	121·92	13·62	123·96	15·29	100·62	7·85
0·00075	281·16	49·34	185·83	32·15	178·58	79·42
0·000255	133·94	53·42	103·05	32·13	53·85	23·55
Totals - -	610·95	184·54	508·99	149·48	399·63	138·52

TABLE C.

Number of Particles in One Gramme of Ignited Soil.

Aldershot Soil.	Aldershot Subsoil.	Altrincham Soil.	Rugby Soil.	Leicester Soil.	South Norwood Soil.
—	—	—	—	—	—
—	—	—	—	—	—
3	1	3	2	5	1
1	2	5	2	3	2
10	8	49	20	21	13
191	185	927	274	199	210
192,120	179,450	85,884	78,676	83,776	98,556
860,600	1,752,200	5,312,800	3,922,200	7,131,000	4,307,900
38,536,000	92,680,000	158,010,000	320,570,000	217,520,000	476,530,000
114,785,000	1,047,500,000	1,120,800,000	2,880,700,000	1,979,600,000	968,060,000
154,373,985	1,142,111,846	1,284,209,668	3,207,341,174	2,204,335,004	1,448,996,682

TABLE D.

Surface Area in Square Centimetres of the Particles in One Gramme of Ignited Soil.

Aldershot Soil.	Aldershot Subsoil.	Altrincham Soil.	Rugby Soil.	Leicester Soil.	South Norwood Soil.
—	—	—	—	—	—
—	—	—	—	—	—
0·59	0·14	0·42	0·29	0·97	0·17
0·10	0·14	0·37	0·16	0·21	0·11
0·18	0·14	0·87	0·35	0·37	0·23
0·84	0·82	4·09	1·21	0·88	0·93
135·80	126·84	60·71	55·61	59·22	69·67
24·33	49·54	150·21	169·42	201·62	121·80
68·10	163·70	279·23	566·49	384·39	842·10
23·45	213·98	228·97	588·48	404·41	197·76
253·39	555·30	724·87	1382·01	1052·07	1232·77

TABLE C 1.

DIGEST of Table "C," in which the Numbers of Particles per gramme in the various ignited soils and subsoils down to the drains are referred respectively to the soil and subsoil of Nottingham as 100 in each case.

Name of Farm.	Relative Numbers of Particles.	
	Soil.	Subsoil.
Nottingham	100	100
Cambridge	75	61
Beddington	46	55
Aldershot Camp	19	394
Altrincham	157	—
Rugby	392	—
Leicester	269	—
S. Norwood	177	—

TABLE E.

INTERNAL SURFACE AREAS OF THE MINERAL PARTICLES IN THE SOILS AND SUBSOILS, TO DEPTH OF DRAINS, PER UNIT SUPERFICIAL AREA OF THE LAND.

Name of Farm.	I. Depth of Soil in centimetres.	II. Depth of subsoil to drains in centimetres.	III. Total internal surface area of soil in square centimetres.	IV. Total internal surface area of subsoil in square centimetres.	V. Total internal surface area of soil and subsoil in square centimetres.	VI. Column V. referred to Nottingham as 100.	VII. Proportion of amounts in column VI. due to soil.	VIII. Proportion of amounts in column VI. due to subsoil.	IX. Internal surface area per centimetre depth of soil.	X. Column IX. referred to Nottingham as 100.	XI. Internal surface area per centimetre, depth of subsoil.	XII. Column XI. referred to Nottingham as 100.	REMARKS.
Nottingham - -	27·9	154·9	24,582	50,598	75,180	100	33	67	881	100	326·6	100	This Table brings out the general similarity between the soils and subsoils of Nottingham, Cambridge and Beddington. There is evidently a great difference between these three and the soil and subsoil of Aldershot Camp.
Cambridge - -	34·3	110·5	24,959	30,063	55,022	73	33	40	728	83	272	83	
Beddington - -	38·1	160·0	21,488	40,780	62,268	83	29	54	564	65	255	78	The Rugby subsoil was not analysed, but the figures for the soil show how widely it differs from those of the farms where true filtration takes place.
Aldershot Camp -	20·3	78·7	7,569	64,275	71,844	96	10	86	373	42	817	250	
Altrincham - -	36·8	—	22,906	—	—	—	—	—	622	71	—	—	
Rugby - - -	25·4	—	74,404	—	—	—	—	—	2,928	332	—	—	

The figures in Tables C and C 1 were obtained by means of the following formula :—

$$n = \frac{6a}{\pi\, d^3\, \rho.\, A}$$

where d is the mean diameter, in cms., of the particles in any fraction obtained by elutriation :

a is the percentage of that fraction :

ρ is the real specific gravity of the particles (assumed to be the same as that of the whole soil) :

A is the sum of the percentages of all the particles in the ignited soil :

n is the number of particles of mean diameter d per gram of the original soil.

Corresponding values for each fraction into which the soil was resolved are substituted in this equation, and the sum of the values for n thus obtained represents the total number of particles in one gram of the soil, or, algebraically :—

$$N = \frac{6}{\pi\, \rho\, A} \left\{ \frac{a_1}{d_1^3} + \frac{a_2}{d_2^3} + \cdots \right\}$$

where N is the total number of the particles in 1 gram of the soil.

From Table C are derived the contents of Table D, by means of the following formula :

$$S = \pi\, d^2\, n$$

where d is the mean diameter of the particles in any fraction :

n is the number of particles of mean diameter, d, per gram of the soil :

S is the surface area, in sq. cms. of the particles of mean diameter d, in 1 gram of the soil.

By adding up the values of S, obtained by substituting values for d and n corresponding to the different fractions, we obtain the total surface exposed by the particles in 1 gram of the whole soil, or, algebraically :—

$$S = \pi\, (d_1^2\, n_1 + d_2^2\, n_2 + \cdots)$$

where S is the total surface of all the particles, in sq. cms., in 1 gram of soil.

In using the formula just given for obtaining the number and surface of the particles per gram of a soil, the values of α, ρ, and A taken were those obtained after ignition, the reasons for this being :—

1. That the values obtained for loss on ignition are by no means due entirely to organic matter, but also to combined water, etc., so that the actual percentage of organic matter was not known.

2. That while organic matter has undoubtedly a considerable effect on the nature of a soil as regards filtration, etc. ; the magnitude of this effect is more or less a matter of conjecture.

Table E is derived from Table D in the following way :—

A section, one centimetre square, is supposed to be cut out of the soil and subsoil to the depth of the drains. If d cms. = depth of soil, then the cubic contents of the section of the soil $= d$ cubic cms.

Again, if ρ_A = apparent specific gravity of the soil, then the weight of the section of soil $= d\, \rho_A$ grams ; and, if S. sq. cms. of surface are exposed by the particles in 1 gram of soil, then the total surface area exposed by $d\, \rho_A$ grams of soil $= d\, \rho_A$. S. sq. cms.

Similarly :—

Total surface area exposed by $d^1\, \rho_A^1$ grams of the subsoil $= d^1\, \rho^1_A\, S^1$ sq cms

$\therefore$ S = Total surface area exposed by $d\rho_A$ grams soil + $d^1\, \rho^1_A$ grams subsoil $= d\, \rho_A\, S + d^1\, \rho^1_A\, S^1$ sq. cms.

After reading this section as it was originally written, Sir William Ramsay suggested to us that it would be better to give the numbers of particles and the surface areas *per cubic centimetre* of soil rather than *per gramme.* This could easily have been done by multiplying the figures per gramme by the "apparent" specific gravity of the ignited soil in question. But we had unfortunately not determined the latter value, and in some cases there was not enough of the sample left to allow of our doing so afterwards. We give below, however, the results obtained by using the *unignited* "apparent" specific gravity as multiplier. In most of the cases the error thus introduced is not large, but it is probably considerable in the soils which contain comparatively large amounts of volatile matter, *e.g.*, in those of Leicester Rugby, and—especially—Altrincham. These results are shown in the following tables B(*a*), C(*a*), D(*a*) and C_1(*a*), which correspond respectively with tables B, C, D and C_1.

TABLE B (*a*).

This shows the "Real" and "Apparent" Specific Volumes of the various soils and subsoils dried at 110° C., together with the deduced percentage Air space or "Porosity."

Name of Farm.	Soil or Subsoil.	Real specific volume of soil or subsoil dried at 110° C.	Real specific volume of the ignited soil or subsoil.	Apparent spec. volume of soil or subsoil dried at 110° C.	Deduced "porosity" or percentage air space.	Weight of water held by 100 grammes of the air-dry soil (grammes.)
Nottingham	Soil	0·39	0·37	0·69	43·5	32·5
Nottingham	Subsoil	0·37	—	0·56	34·0	20·1
Cambridge	Soil	0·38	0·37	0·70	45·7	30·3
Cambridge	Subsoil	0·38	—	0·55	31·0	14·3
Beddington	Soil	0·40	0·38	0·71	43·7	37·0
Beddington	Subsoil	0·40	—	0·54	26·0	10·5
Aldershot Camp	Soil	0·40	—	0·68	41·2	29·4
Aldershot Camp	Subsoil	0·39	—	0·68	42·6	28·8
Altrincham	Soil	0·42	0·34	1·17	64·1	71·5
Altrincham	Subsoil	—	—	—	—	—
Rugby	Soil	0·39	0·35	0·60	35·0	55·9
Rugby	Subsoil	—	—	0·62	—	—
Leicester	Soil	0·40	0·37	0·80	50·0	47·5
Leicester	Subsoil	—	—	0·56	—	—
South Norwood	Soil	0·43	0·37	0·82	47·6	64·3
South Norwood	Subsoil	—	—	0·53	—	—

TABLE C. (*a*).

Number of Particles in One Cubic Centimetre of Ignited Soil.

Mean Diameter of Fraction in Centimetres.	Nottingham Soil.	Nottingham Subsoil.	Cambridge Soil.	Cambridge Subsoil.	Beddington Soil.	Beddington Subsoil.
1·0	—	—	—	—	—	—
0·35	4	4	—	7	3	6
0·25	—	—	3	16	—	—
0·15	6	11	4	16	3	9
0·075	33	89	43	133	16	38
0·0375	711	1,982	796	1,981	349	683
0·015	142,720	151,410	187,670	154,620	123,000	59,116
0·003	6,218,000	854,230	6,287,000	984,920	5,031,800	511,430
0·00075	229,430,000	49,505,000	150,780,000	33,126,000	142,900,000	82,827,000
0·000255	945,500 000	463,650,000	723,410,000	286,390,000	372,720,000	212,430,000
Totals - -	1,181,291,474	514,162,726	880,665,516	320,657,693	520,775,171	295,828,282

TABLE D. (*a*).

Surface Area, in Square Centimetres, of the Particles in One Cubic Centimetre of Ignited Soil.

Mean Diameter of Fraction in Centimetres.	Nottingham Soil.	Nottingham Subsoil.	Cambridge Soil.	Cambridge Subsoil.	Beddington Soil.	Beddington Subsoil.
1·0	—	1·03	—	—	0·78	2·54
0·35	1·63	1·68	—	2·55	1·07	2·43
0·25	—	—	0·63	3·22	—	—
0·15	0·36	0·78	0·33	1·15	0·18	0·59
0·075	0·59	1·58	0·76	2·35	0·26	0·68
0·0375	3·14	8·76	3·51	8·76	1·54	3·02
0·015	100·90	107·02	132·65	109·28	88·88	41·78
0·003	175·80	24·15	177·76	28·00	142·28	14·47
0·00075	405·40	87·48	266·48	58·55	252·51	146·37
0·000255	193·15	94·71	147·44	58·59	76·15	45·40
Totals - -	880·97	327·19	730·56	272·45	563·65	255·28

TABLE C. (*a*).

Number of Particles in One Cubic Centimetre of Ignited Soil.

Aldershot Camp Soil.	Aldershot Camp Subsoil.	Altrincham Soil.	Rugby Soil.	Leicester Soil.	South Norwood Soil.
—	—	—	—	—	—
—	—	—	—	—	—
4	1	3	3	6	1
1	3	4	3	4	2
15	12	42	34	26	16
280	272	795	460	248	257
281,840	263,610	73,672	132,175	104,300	120,535
1,262,500	2,574,000	4,558,400	6,589,380	8,878,100	5 268,700
56,532,000	136,145,000	135,570,000	538,559,000	270,814,000	582,805,000
168,390,000	1,538,760,000	961,660,000	4,839,690,000	2,464,620,000	1,183,950,000
226,466,640	1,677,742,898	1,101,862,916	5,384,971,055	2,744,416,684	1,772,144,511

TABLE D. (*a*).

Surface Area, in Square Centimetres, of the Particles of One Cubic Centimetre of Ignited Soil.

Aldershot Camp Soil.	Aldershot Camp Subsoil.	Altrincham Soil.	Rugby Soil.	Leicester Soil.	South Norwood Soil.
—	—	—	—	—	—
—	—	—	—	—	—
0·87	0·21	0·36	0·49	1·21	0·21
0·15	0·21	0·32	0·27	0·26	0·13
0·26	0·21	0·75	0·59	0·46	0·28
1·23	1·20	3·51	2·03	1·10	1·14
199·22	186·33	52·09	93·42	73·73	85·21
35·69	72·77	128·88	284·63	251·02	148·62
99·90	240·48	239·58	951·50	478·57	1,030·30
34·40	314·34	196·46	988·65	503·49	241·86
371·72	815·75	621·95	2321·57	1309·84	1507·75

TABLE C_1 (*a.*)

DIGEST of TABLE C (*a*), in which the Numbers of Particles *per cubic centimetre* in the various ignited Soils and Subsoils are referred respectively to the Soil and Subsoil of Nottingham as 100 in each case.

Name of Farm.	Relative Numbers of Particles.	
	Soil.	Subsoil.
Nottingham	100	100
Cambridge	75	62
Beddington	44	57
Aldershot Camp	19	326
Altrincham	100	—
Rugby	456	—
Leicester	232	—
South Norwood	150	—

Taking Tables C and D together, the first thing that strikes one is that, as regards *number* of particles, the coarser fractions are negligible in comparison with the "silt," "dust" and "clay," or with the two last alone. Indeed, in heavy soils the "clay" itself practically determines the number of particles present. The great difference between the number of particles in a light soil on the one hand, and in a heavy loam or clay soil on the other, is also noteworthy. For instance, these numbers in the case of the Aldershot Camp and Rugby soils are, approximately, 1 : 20. On closer examination, it will be observed that the chief difference between these two soils is in the fraction termed "clay," *i.e.*, the fraction whose particles are of smallest diameter. The effect of this is that the total air space in the Rugby soil, which may be taken *roughly* as equal to that in the Aldershot Camp soil, is divided up into twenty times the number of spaces existing in the latter. In other words, each individual air space in the Rugby soil is only one-twentieth as large as each air space in the Aldershot Camp soil. It is evident from this that filtration through the Rugby soil must be a much more difficult process than through the Aldershot Camp soil, owing to friction between the water and the soil particles. This fact—as is well known in practice—is of great importance in its bearing upon sewage filtration through soil, not merely when looked at from a physical standpoint, but also with regard to bacterial action. If the air spaces are very small, it is easy to understand that aerobic bacteria find it difficult to work, not only from lack of oxygen, but also because the products of their action are not carried away with sufficient rapidity. It would be interesting to analyse the air drawn from different depths in the ground at a sewage farm with a porous subsoil, and to examine the soil and subsoil themselves for absorbed gases.

Other points to be noted in tables (C) and (D) are (1) The ratio of the number of "clay" particles to the number of particles other than "clay"; and, depending upon this, (2) the corresponding ratios of the surface areas. This is readily seen from the following figures :—

SURFACE SOILS.	Notts.	Cambs.	Beddn.	Ald. C.	Altn.	Rugby	Lestr.	S. Norwood
No. of "clay" particles ...	4	4·6	2·6	3	7	9	9	2
No. of particles other than "clay"	1	1	1	1	1	1	1	1
Surface of "clay" particles ...	1	1	1	1	1	1	1	1
Surface of other particles ...	3·6	4	6	10	2	1·3	1·6	5
SUBSOILS.								
No. of clay particles ...	9	8	2·6	11				
No. of other particles ...	1	1	1	1	—	—	—	—
Surface of clay particles ...	1	1	1	1				
Surface of other particles	2·4	3·6	5	1·6				

A glance at the above ratio figures shows that the surface soils in which we know that true filtration takes place, viz. :—Aldershot Camp, Nottingham, Cambridge and Beddington, have very similar values when contrasted with the values for heavy soils like those of Rugby and Leicester. The large quantity of peaty matter in the Altrincham soil makes it difficult to draw any conclusion with regard to it. South Norwood soil is an apparent exception to the other heavy soils. It is just possible that from its being one of the first to be elutriated, the silt and dust were not so well separated from the clay as in other cases; but on the other hand, the modifying treatment to which this naturally heavy soil has been subjected for a great many years by sewaging and by digging in of ashes (the presence of which latter in the sample for analysis was easily detected) may be sufficient to account for the apparent anomaly. It would be well, however, to have a second corroborative mechanical analysis made.

With respect to the four subsoils examined, that of Aldershot Camp alone approached in its nature to a soil, the others being largely composed of more or less coarse gravel, especially Beddington. The gravelly nature of these three subsoils is of great importance, both with regard to filtration and to bacterial action, because, as has been pointed out above, the particles being comparatively few in number, the individual air spaces are relatively large, and the easy passage of water down to the depth of the drains is assured. Moreover, in consequence of comparatively free aeration, aerobic bacterial action must be greatly facilitated. With regard to Aldershot Camp, however, it will be observed that the subsoil is of a very much closer texture than the soil, so that in its case the above conditions are reversed. The result, presumably, would be greater difficulty in maintaining good aeration throughout the whole depth of the filtering medium; but this is merely an opinion.

Turning to the ratios of internal surface area, we see that the Nottingham, Cambridge and Beddington soils shew somewhat similar figures, as was the case with the number ratios. Aldershot soil, however, has a ratio which is quite different from these, an explanation of which is given below. The values for Rugby and Leicester soils are similar, while Altrincham and South Norwood are again anomalous for the reasons stated above.

Comparison of Nottingham, Cambridge and Beddington soils.

The great purity of the Nottingham effluents suggest that the soil and subsoil through which they pass constitute a more or less ideal filtering medium. For this reason it has been thought advisable to shortly compare each of the other soils and subsoils with those of Nottingham.

Looking at Tables C and D, it is at once evident that there is a very striking similarity between the soils and subsoils of Cambridge and Nottingham. Both soils are made up largely of the finer particles—Nottingham rather more so than Cambridge—and both have a reasonable, though not large, percentage of "clay" particles. Both soils, too, are of about the same depth and lie on subsoils also very similar, both as regards general nature and depth to the drains, Cambridge subsoil—as is the case with the soil—containing rather fewer particles per gram than that of Nottingham. From the mechanical analyses, therefore, we should expect Nottingham and Cambridge soils to produce very similar results as regards sewage filtration, and, so far as these results can be compared, they are fairly well in accordance with this view.

Beddington soil and subsoil, while generally of a similar nature to those of Nottingham and Cambridge, and having about the same depth, are distinctly coarser, *i.e.*, contain fewer particles per gram in both soil and subsoil. The mechanical analyses, however, from their general agreement with those of Nottingham and Cambridge, indicate that, were it used wholly for filtration instead of surface irrigation, the Beddington farm would purify a large quantity of sewage and produce from it an effluent of high class.

Comparison of the Soils and Subsoils of Nottingham and Aldershot Camp.

Referring to Table A, it will be seen that the soil at Aldershot Camp farm contains over 90 per cent. of the coarser particles, including 80 per cent. of sand, the percentage of finer particles being only about 8. Though there is some matter in the Nottingham soil coarser than in that of Aldershot, there is also 30 per cent. of the finer ingredients. The comparatively large diameter of the particles constituting the "sand" fraction, together with the low percentage of finer matter, accounts for the small number of particles per gram in the Aldershot soil as compared with that of Nottingham (Table C). But the difference between the two soils is brought out most clearly in Table D, where it is shewn that the "sand" fraction provides more than half of the total internal surface exposed in the Aldershot Camp farm soil. In the Nottingham soil on the other hand the surface of the "sand" particles is only one-tenth of the whole. This, therefore, explains the somewhat curious surface ratio obtained for Aldershot Camp soil.

The subsoils of Nottingham and Aldershot are in every way a contrast to each other, 53 per cent. of the former consisting of particles coarser than "sand" against 14 per cent in the latter. The percentage of the finer particles in the Nottingham subsoil is only about one-third of that in the Aldershot subsoil, the respective "clay" percentages being 0·6 and 2·3.

NOTE.—It was repeatedly noticed when making these analyses that the "clay" consisted of particles obviously widely divergent in diameter (speaking comparatively). It is probable that a greater proportion than usual of the "clay" in the Aldershot subsoil, which, though of exceedingly fine texture, was not plastic like the clay of a heavy clay soil, consisted of the comparatively large particles which exist *as such*, rather than of the colloïd substance which one may term *true clay*. This is one of the many interesting points in the present work which require further investigation. Only the relatively short time at our disposal prevented us from increasing the number of separations.

Comparison of Nottingham Soil with the Rugby and Leicester Soils.

In the Nottingham soil on the one hand, and the soils of Rugby and Leicester on the other, there is a great contrast as regards total number of particles. The difference, however, is not very marked except in the "clay" fractions, where Rugby has three-and-a-half times and Leicester three times as many particles per gram as Nottingham.

The subsoils of Rugby and Leicester were not analysed, but a cursory examination was sufficient to show that each was a yellow clay of a very close texture indeed.

The result of these comparisons, therefore, is merely to emphasize what has been said above concerning filtration, aeration and bacterial action in heavy soils.

Comparison of the Nottingham Soil with the South Norwood Soil.

A glance at Tables C and D brings to light the unexpected fact that the soils of Nottingham and South Norwood are similar in all the fractions excepting those of "dust" and "clay," where the numbers are considerably greater in the case of South Norwood. The latter appears to be a much altered clay soil, and its present condition is a striking instance of the effect of ploughing, sewaging and the judicious application of ashes in making a heavy clay more friable.

The South Norwood subsoil is a very stiff clay; it was not analysed.

Rate of Filtration of Water through Soils.

Experiments have been in progress for a considerable time on the comparative rate at which water, under a given head, filters through a column of definite length of the various soils and subsoils, but the results are not consistent enough to allow of their being quoted. These filtration results, therefore, have been considered as merely qualitative, and referred to as such in the General Report (Part I.) and in this Report. Speaking generally, however, they seem to indicate that the rates of filtration may be roughly proportional to the numbers of particles per gram of the soil, as given in Table C. Unfortunately, filtration results obtained in this way are probably not typical of what takes place in the soil in a field, because it is impossible to reproduce the natural conditions in the laboratory. Attempts made at the farms by Mr. Kershaw to bore out sections of the soils of about four inches diameter with a steel cutting tube were unsuccessful, owing to the baffling effect of small stones. The best plan to follow would probably be that which has sometimes been adopted in America, viz., to obtain a column by digging away the surrounding soil, and then to slip over that column a cylinder of slightly larger diameter, filling up the space at the sides with melted paraffin. When the latter has solidified, the column is cut off at the bottom with a spade and removed to a convenient place for the filtration experiments. In this way the soil is not disturbed, but remains in its natural condition.

In conclusion, the results obtained in the course of this work, while much too few to allow of an attempt being made to draw general deductions, are of some interest. They show clearly that it is possible to say from the mechanical analysis of a soil whether or not it would be suitable for sewage purification by filtration, and the same thing holds in a lesser degree as regards suitability for surface irrigation. Further, they tend to indicate that the maximum number of particles per gram of soil, which is allowable if the filtration is to be efficient (a suitable subsoil being assumed), is somewhere about 1,000 millions. We bring forward this figure with reserve, of course, as it requires corroboration from the examination of further samples. As has been already said in the General Report (Section I. Sub-section II.), if a sufficient number of such mechanical analyses were available for reference, they would afford excellent data as to the volume of sewage of given nature and strength which any particular soil might reasonably be expected to purify.

Our best thanks are due to Mr. G. B. Matthews, F.R.S., and to Sir William Ramsay for much kind help and criticism in connection with the foregoing work upon soils.

G.M.
R.S.F.

Estimation of the Lime in the Soils and Subsoils of the Eight Principal Farms.

(*a*) Lime dissolved in 24 hours by water alone;

(*b*) Lime dissolved in 48 hours by water saturated with carbon dioxide.

This estimation was made by the method described by Dr. A. F. Holleman in a paper entitled "Die Bekalkung von steifen Kleyboden" {*Groningen; Die Land Versuchs-Stationen, Vol.* 41, *p.* 37 (1892)}; only, by an oversight, the lengths of time allowed for solution were in this case reversed—*i.e.*, Dr. Holleman gave 48 hours for the action of the water and 24 hours for the action of the carbonic acid water. The results which we have obtained, however, are strictly comparable with one another, and show the relative amounts of lime extracted from the soils and subsoils under the above conditions.

The following was the procedure adopted:—

(a) *Lime dissolved in* 24 *hours by water.*

Twenty grammes of air-dried soil or subsoil were thoroughly mixed with one litre of water, and the whole was allowed to stand in a stoppered bottle for 24 hours, with occasional shaking. The muddy liquid was then filtered, and 500 c.c. of the filtrate were evaporated to dryness after the addition of a few drops of glacial acetic acid. The residue was now dissolved in water and a little acetic acid, filtered if necessary, rendered alkaline by ammonia, and the lime thrown down by ammonium oxalate. After standing for 24 hours the precipitate was filtered off, washed, dissolved in dilute hydrochloric acid, re-precipitated with ammonia and ammonium oxalate, and allowed to stand for another 24 hours. The precipitate was now again filtered, washed free from chloride, dissolved in dilute sulphuric acid, and the solution titrated with decinormal permanganate. From the amount of the latter used up, the lime present in the solution was readily calculated.

(b) *Lime dissolved in* 48 *hours by water saturated with carbonic acid.*

Twenty grammes of the air-dried soil or subsoil were thoroughly mixed with one litre of water, and carbon dioxide was passed at a fairly brisk rate through the muddy solution for an hour and a-half. The bottle was then stoppered and allowed to stand for 48 hours, with occasional tilting up, in order to diffuse the soil through the liquid.* The lime which went into solution was then determined exactly as described above.

The following table gives the percentage figures for the lime extracted, as above, from the various *air-dried* soils and subsoils (the Altrincham soil contained about 9 per cent. of moisture after being air-dried; the South Norwood soil about 7 per cent.; the Leicester soil about 5 per cent.; and the Rugby soil about 4 per cent. In the loamy soils and sandy or gravelly subsoils the moisture was, of course, very small. It was not determined in the clay subsoils):—

* The bottle should not be shaken, though this was done in the case of the earlier samples.

Air-dried Soils.

	Percentages.	
	Lime dissolved in 24 hours by water.	Lime dissolved in 48 hours by water saturated with carbonic acid gas.
Nottingham	0·009	0·060
Cambridge	0·085	0·530
Beddington	0·029	0·215
Aldershot Camp	0·004	0·030
Altrincham	0·045	0·197
Rugby	0·051	0·482
Leicester	0·073	0·554
South Norwood	0·073	0·382

Air-dried Subsoils.

Nottingham	0·017	0·070
Cambridge	0·058	0·582
Beddington	0·026	0·268
Aldershot Camp	0·005	0·018
Altrincham	0·016	0·068
Rugby	0·071	0·969
Leicester	0·017	0·467
South Norwood	0·020	0·076

A glance at the above table shows that the Aldershot Camp farm soil and subsoil contained, as one would expect, but little lime, and there was relatively only a moderate quantity of lime in solution in the effluents from there. The large amounts found in the light soil and subsoil at Cambridge are no doubt the result of the heavy liming with lime sludge (from the sewage treatment) which the land received there some years ago.

These results, taken in conjunction with the examination of the effluents from the different farms, indicate that a soil does not require to be rich in lime for nitrification to go on actively in the treatment of an ordinary sewage. It would make an interesting experiment to lime a portion of the ground at Aldershot Camp more heavily than the rest and to note whether there was any appreciable difference in the effluents obtained from that portion.

SUMMARY OF CHEMICAL RESULTS AND CONCLUSIONS.

The subject of the purification of sewage by land is so complex and involves so many factors that it is very difficult to give a satisfactory short summary of the chemical results of a long investigation on the subject. Those results have been given in detail in the separate Reports, Tables of analysis and Curves appertaining to each farm. Enough has been said already to show that the conditions at the various farms differ so much from one another that only very broad comparisons can be drawn.

The process of purification of sewage on land is, as is well known, one depending ultimately on efficient oxidation—*i.e.*, on indirect oxidation by the oxygen of the air through the agency of nitrifying organisms. These organisms are of course active in the surface soil where the aeration is readily kept up, though aeration here must necessarily vary with the porosity and texture of the soil itself. It is obvious, therefore, that what is wanted in the soil and subsoil of a filtration farm is good aeration combined with as rapid filtration as is consistent with good purification; or, in other words, we require that in the soil and subsoil neither the aggregate number of particles per unit volume of soil nor the aggregate filtration surface exposed by those particles shall fall below or exceed certain limits. In order, therefore, to be able to form an approximate estimate of the purifying effect which any particular soil is likely to exercise upon a given sewage, we ought to know:

(*a*) The volume and strength of the sewage.

(*b*) The quality of soil and subsoil as determined by mechanical analysis.

(*c*) If possible, the average rates of filtration through the soil and subsoil.

(*d*) It may also be desirable to determine the amount of lime or other chemical constituent of the soil.

The subject is treated in detail in the section of this Report which deals with Soils.

The appended Tables (A) (B) and (C), a few pages further on, show respectively:

(A.) The average chemical composition of the different sewages treated on the eight principal farms under observation.

(B.) The average chemical composition of the different effluents.

(C.) The *approximate* percentage purification effected at each farm, as calculated by the reduction in (*a*) albuminoid nitrogen; (*b*) "oxygen absorbed" from permanganate.

The last table is given for the convenience of those who are in the habit of gauging purification in this way, but it must again be remembered that the calculation is merely empirical, the organic matter in a purified effluent being totally different as regards fermentability from the organic matter in the original sewage.

Sewages.—The differences shown by the various sewages as regards organic strength and quality have already been dwelt upon in the separate Farm Reports, and they are also well seen by a reference to Diagrams 1 and 2 (Hourly Sewage Samples).

Effluents.—With respect to effluents, it will be observed that neither in this nor in the General Report (Part I.) has any fixed chemical standard for effluents been specified. The reasons for not advancing a definite opinion upon this point in the meantime are discussed a little further on under the heading "Chemical Standards of Purity for Sewage Effluents." At the same time it should be said here, for the guidance of the reader, that in endeavouring to arrive at the quality of any particular effluent, or of the effluents generally from any one farm, the following points among others, have been borne in mind:—

1. The smell of the effluent and its general appearance with regard to colour, solids in suspension, etc.

2. How the effluent would be judged (speaking approximately) by the Mersey and Irwell provisional standard as regards albuminoid nitrogen and "oxygen absorbed" from permanganate (but allowing to some extent for the "oxygen absorbed" being determined with strong permanganate at 80° F. and not with weak permanganate at 60° F.).*
3. Whether or not it withstood the incubator test.
4. The amount of dissolved oxygen present at the time of analysis,† and the comparison of this with the quantity present when the sample was drawn, having regard here also to whether a surface irrigation or a filtration effluent was in question; further whether any oxygen remained after incubation either at atmospheric temperature or at a temperature of 26·7° C. (80° F.).
5. The amount of nitrate present, and how far that nitrate was reduced upon incubation.
6. The approximate ratio of oxidized (*i.e.*, nitric + nitrous) nitrogen to the albuminoid and to the total organic nitrogen, and also to the total unoxidized nitrogen.

The purification results at the different farms may be summarised as follows :—

1. Cambridge (*Filtration, mostly without cropping*).

The Cambridge farm treats, on a good porous soil and subsoil, an exceptionally large volume of a somewhat weak domestic sewage, which however contains in the aggregate a very large quantity of organic matter—more than half as much again as the organic matter treated per acre at Nottingham (compare diagrams 3 and 4). The result is a dilute effluent which is usually from a chemical point of view good, and sometimes very good. At the same time the organic matter left in some of the less highly purified effluents is of a somewhat putrescible character, as judged by the incubator test, though there is nearly always enough nitrate present to keep the liquid sweet upon incubation. The number of particles‡ in unit weights of ignited soil and subsoil, taking the numbers at Nottingham as 100 in each case, are :—soil 75; subsoil 61; the number of particles in unit volumes (Nottingham = 100) are :—soil 75; subsoil 62. The relative calculated§ *internal* filtering area at Cambridge per unit of surface, down to the drains, works out to about three-quarters that at Nottingham, the difference being in the subsoil, but depth for depth there is not a great deal of difference between the two (about 12 per cent.), the drain pipes being laid deeper at Nottingham. The rate of filtration at Cambridge must be a medium rate, probably rather faster than that at Nottingham. If, therefore, the two farms were laid out in the same way, and treated the same sewage in equal volumes per acre, we should expect the results to be much the same, though probably with a slight balance in favour of Nottingham.

2. Altrincham (*Filtration, with cropping*).

Altrincham also treats a large volume of a weak domestic sewage, about three-fourths of the volume at Cambridge (cf. diagram 3), but on a porous partially peaty soil, overlying sand admixed with a little gravel. We have not sufficient data to give either the relative amount of organic matter treated per acre, though this must be large, or the approximate relative internal filtering area of the Altrincham soil and subsoil down to the drains. The number of particles in unit weight of ignited soil (Notts = 100) is 157, and in unit volume 100. The rate of filtration at Altrincham is probably fairly rapid. The result is an effluent which is on the whole fairly satisfactory chemically, but the farm had apparently rather too much to do at the time of our observations. As regards the treatment of large volumes of weak domestic sewage, Cambridge and Altrincham are more or less parallel; but in the nature of the soil and subsoil and in the depth to the drains the two differ materially.

---

* cf. Introduction; also Report on Methods of Chemical Analysis (Vol. IV. Part V. Fourth Report of Royal Commission on Sewage Disposal.)

† A fully aerated sample would contain roughly about 7 cubic centimetres of oxygen per litre, *i.e.*, 7 volumes of oxygen per 1,000 volumes of water.

‡ As already stated, these numbers of particles (in this and the other soils and subsoils) refer to the ignited soil or subsoil, and therefore take no account of particles of organic matter present.

§ This calculation is of necessity only an approximate one.

3. Nottingham (*Filtration, with cropping*).

Nottingham treats, on an excellent loamy soil and gravelly subsoil, a medium volume of a rather strong sewage containing 40 per cent. of trade refuse, the aggregate organic matter treated per acre at Nottingham being about two-thirds that at Cambridge (Diagrams 3 and 4). The number of particles in unit weight of ignited soil and subsoil is here taken at 100 in each case, for the purpose of comparison with the soils and subsoils at the other farms, and the same with regard to unit volumes of the soil and subsoil. The relative calculated internal filtering area per unit of surface down to the drains is taken as 100 (surface soil = 33 ; subsoil = 67), being about one-third greater than at Cambridge, and the rate of filtration is probably somewhat slow. The drain pipes are laid very deep, the average depth being about 6 feet. The result of the treatment at Nottingham is an effluent of altogether exceptional quality, clear and sparkling, and approaching in the best samples within measurable distance, from a chemical point of view, of a drinking water.

4. Aldershot Camp (*Filtration, with cropping*).

At Aldershot Camp a medium volume of a very strong and highly ammoniacal sewage is treated on a relatively coarse sandy soil overlying a fine sandy subsoil containing a great deal of iron. The aggregate organic matter treated per acre is on the whole, perhaps, somewhat greater than at Nottingham (compare diagram 4), but there is no trade refuse mixed with the sewage. The average depth to the drains is about 3 feet 3 inches, and the rate of filtration through such a fine sandy subsoil must be rather slow. The numbers of particles in unit weights of ignited soil and subsoil (Notts = 100), are :—soil 19 ; subsoil 394 ; and in unit volumes they are :—soil 19 ; subsoil 326. The relative calculated internal filtration surface area down to the drains is almost the same as that at Nottingham, but it is differently divided between surface soil and subsoil in the two cases. The general result of the treatment at Aldershot is a highly nitrated effluent, still containing in some instances a considerable amount of organic matter, not much of which however is of a rapidly fermentable character as judged by the incubator test, and the nitrate present is always much more than sufficient to keep the effluents sweet. They often contain, however, considerable quantities of very flocculent vegetable matter, coloured by oxide of iron, washed from the drain pipes.

It will be observed that, apart from texture, the conditions for the aeration of the soil and subsoil are the reverse at Aldershot Camp to what obtain at Nottingham and Cambridge, and are probably less favourable, for at the former we have a coarse sand resting upon very fine sand, while at the two latter a fine loam rests upon coarse sand and gravel.

5. Croydon, Beddington (*as a Filtration farm, with cropping*).

Although Beddington is primarily a surface irrigation farm, a small portion of it is drained, and reference may therefore be made to that portion here. The soil and subsoil are, generally speaking, directly comparable in texture with those at Nottingham and Cambridge, though the Beddington subsoil is much the most stony of the three. The numbers of particles in unit weights of the ignited soil and subsoil (Notts = 100) are :—soil, 46; subsoil, 55 ; and in unit volumes they are :—soil 44, subsoil 57. Taking the average depth down to the drains at 6 feet 6 inches, the relative calculated internal filtration area per unit of surface is about four-fifths that at Nottingham, and these areas are divided in much the same way between soil and subsoil at both places. The rate of filtration must also be somewhat similar to the rates at Nottingham and Cambridge, though no doubt appreciably faster. The results of the analysis of the second field filtration effluents obtained in the special experiment show what a high degree of purification, chemically speaking, can be obtained by using Beddington as a filtration farm. The soil and subsoil being, however, distinctly coarser than those at Nottingham would probably not produce (under exactly similar conditions) quite such good results as we have obtained at the latter place ; on the other hand aeration would be easier at Beddington.

5a. Croydon, Beddington (*as a Surface Irrigation farm*).

Since the surface soil at Beddington is about 15 inches deep, we are to a certain extent dealing here with a shallow filtration farm, with very good soil for the purpose of sewage purification. But with our present data it is impossible to say how much of the purification effected at Beddington is due to filtration through the top soil and how much to surface irrigation pure and simple. The sewage is practically a domestic one, of moderate strength—probably of about average strength. The volume of sewage treated per acre—exclusive of storm water—was very large for a surface irrigation farm, being only a little less than that at Nottingham and a little more than at Rugby and Aldershot Camp, while the aggregate organic matter (again excluding storm water) treated per acre was less than at Rugby (*see* diagrams 3 and 4). The variations in flow and the additional matter to be dealt with, owing to sudden influxes of storm water at Beddington, must add greatly to the difficulty of management. The analytical results of the final effluents show that the Beddington farm, used for broad irrigation under the conditions detailed in the Engineering Report, is capable of producing a high-class effluent, and does so sometimes but not always, the inference being that the land had rather too much to do.*

6. Rugby. High Level Farm (*Surface Irrigation on stiff soil with underdrains*).

Rugby was originally chosen as an example of a sewage farm with a heavy loam soil, *i.e.*, a soil midway between a light loam and a clay. We had very great difficulty in finding a suitable farm with this type of soil, and Rugby was ultimately fixed upon as being on the whole the most suitable. As will be seen, however, from a comparison of the mechanical analysis of the Rugby surface soil with those of Leicester and South Norwood, that at Rugby is apparently—contrary to expectation—more of a clay than the others. But gravel "pockets" occur in the subsoil at Rugby, and these must to some extent increase the purification by the filtration which takes place through them. The surface soil itself is about 10 inches deep and it overlies yellow clay, the average depth of the drains being about 3 feet 9 inches. If we assume, *merely for purposes of comparison*, that the Rugby surface soil acts as a filter, then its relative calculated internal filtration area is 99 (Nottingham soil + subsoil together = 100.) But we know, of course, that it cannot act as a filter to any great extent, and this figure is therefore adduced merely to show that the internal filtration surface of a soil must not exceed a certain maximum. The number of particles in unit weight of the ignited soil (Notts = 100) is 392, and in unit volume 456.

The sewage at Rugby is domestic, but it also contains some engine oil, and the volume treated there per acre is almost the same as at Aldershot Camp. The Rugby sewage is, however, not quite so strong organically, though it contains more suspended solids, and hence the aggregate organic matter treated per acre of irrigable area is rather less (*see* diagrams 3 and 4). Still, the amounts of sewage matter to be purified per acre in the two cases, in almost equal volumes of liquid, are sufficiently near to make a rough comparison of interest. At Aldershot, as already seen, we have one filtration of the sewage through sand, with the production of a highly nitrated effluent. At Rugby, on the other hand, the effluent from half of the sewage, passed for the most part over† one (larger) plot of ground, is mixed with the other half of the sewage, and this mixture is run over a second (smaller) plot, the result being an effluent of quite a different character from that at Aldershot, *i.e.*, much less highly nitrated, but at the same time containing less total nitrogen, less organic nitrogen, and less oxidizable matter generally. Whether this greater decrease in nitrogen is brought about wholly through greater absorption by plants (greater than is possible with filtration through cropped sandy soil), or partly also through the mutual decomposition of nitrate and ammonia by the agency of microbes, would be an interesting point to know.

The Rugby soil is thus capable of producing a very fair surface irrigation effluent of even composition, as was shown by the samples which were drawn and examined in spring; but the quality of the summer samples indicated that the area of land in use at that time was insufficient.

---

* Since the foregoing observations were made, some bacterial filters have been erected at Beddington, with a view to lessening the work laid upon the land.

† The temperature of the Rugby effluents indicated that they were mainly from surface irrigation.

7. Leicester (*Surface Irrigation over clayey soil with underdrains*).

The surface soil at Leicester is of a stiff clayey nature, from 6 to 12 inches deep, overlying $2\frac{1}{2}$ to 3 feet of yellow clay, which in its turn rests upon hard boulder clay and the Keuper marl. The drains are about 4 feet deep. The mechanical analysis of the soil indicated that it was really less stiff than the surface soil at Rugby, but the clay subsoil at Leicester is of a more uniform character than the Rugby subsoil. Taking the number of particles in unit weight and in unit volume of the Nottingham ignited soil at 100 in each case, the number in unit weight of the Leicester soil is 269, and in unit volume 232.

The sewage contains about one quarter of its volume of manufacturing refuse of different kinds, and is of moderate strength as regards nitrogenous matter, though it has in it a relatively large proportion of oxidizable substance, this last being no doubt largely due to the trade refuse present. The actual volume treated per acre of irrigable area is as nearly as possible half that of Nottingham, and the aggregate organic matter also about half (compare diagrams 3 and 4), although the suspended solids going on to the land are in larger proportion than this. Treatment over the first field (arable) removes the larger part of the impurities, more especially as regards suspended solids. The final effluents, from treatment over two or three fields (the second and third field being usually rye-grass or pasture), varied considerably in quality, and might be described as moderate, chemically speaking; it should, however, be added that they withstood the incubator test very fairly, *i.e.*, that their keeping property was better than some of the figures of analysis would lead one to expect. The sewage is no doubt a difficult one to treat on such a soil, especially as the ground has a strong tendency to crack in dry weather and thus to let unpurified sewage direct into the drains. This last circumstance of course emphasises the necessity for repeated treatment under such conditions. The results, however, show that with careful management surface irrigation several times over under-drained clay land may be trusted to produce a fair chemical effluent.

8. South Norwood (*Surface Irrigation over fairly stiff soil, with very little underdrainage*).

At South Norwood the surface soil is less stiff and tenacious than that at Leicester, and this is clearly brought out by the mechanical analysis. It is, however, a little shallower than the Leicester surface soil, viz., from 6 to 10 inches deep. The subsoil is London clay. Taking the number of particles in unit weight of the Notts ignited surface soil at 100, Leicester gives 269 and South Norwood 177, the respective numbers in unit volumes being 232 and 150. The presence of ashes was easily discernible in this soil.

The sewage at South Norwood is purely domestic and it is rather weak. The volume per acre of irrigable area is about five-sevenths that at Leicester and about one-third that at Nottingham, but on the other hand, as at Beddington, the whole of the storm water (amounting on occasions to five times the dry weather flow) is treated at South Norwood, which must of course be a great strain on the farm. Excluding storm water, the actual organic matter dealt with per acre is only about half that at Leicester and one quarter that at Nottingham (diagrams 3 and 4). The effluents varied in appearance, the general effluents evidently containing rather more suspended matter than the other final effluents, which might show only a trace of this. Speaking generally, they were of moderate quality. That the land was getting too much to do at the time of our observations was fully recognised by the local authorities, who have been for some time past extending their bacterial filters with a view to lightening the burden laid upon the soil. But here again, as at Leicester, we have sufficient data to show that a fair chemical effluent can be obtained by surface irrigation over a lightened clayey soil, mostly laid out in rye grass, which is not under-drained.

Short comparison of results at Leicester and South Norwood.

It is difficult to compare the results obtained at Leicester and South Norwood respectively, since the conditions, apart from the question of drainage, are only to some extent analogous. But taking everything into account, it would appear that on the whole the system followed at Leicester, viz.: surface irrigation several times over clayey soil with under-drains in the clay subsoil, is capable of purifying more sewage than that in use at South Norwood—surface irrigation over several plots of undrained clayey soil. In other words, there would seem to be sufficient percolation at Leicester, partly no doubt through small fissures, but partly also in the immediate neighbourhood of the drain pipes, to materially influence the result for the better. (Compare Leicester Farm Report; note by Dr. Aitken upon the permeability of clay soils.) At the same time the temperature of the final effluents, both at Leicester and South Norwood, differed very little from the temperature of the air at the time of drawing, which is an argument against much percolation having taken place at Leicester.

The different texture of the various soils and subsoils is well seen from the following short table, which gives *approximately* the *relative* numbers of particles in unit weights of the ignited soil and subsoil, respectively, and also in unit volumes, referred to the numbers at Nottingham as 100 in each case, for purposes of comparison.

Name of Farm.	Unit Weight.		Unit Volume.	
	Soil.	Subsoil.	Soil.	Subsoil.
Nottingham	100	100	100	100
Cambridge	75	61	75	62
Beddington	46	55	44	57
Aldershot Camp	19	394	19	326
Altrincham	157	—	100	—
Rugby	392	—	456	—
Leicester	269	—	232	—
South Norwood	177	—	150	—

Note.—As the above table takes no account of the particles of organic matter in the soil, it is only approximate. The organic matter (decomposed peat) was so abundant in the Altrincham soil that the figures given for it cannot be regarded as of much value (cf. Section upon Soils).

Before concluding this summary, one or two points may be touched upon, having reference to some of the remaining sewage farms where only a few observations were made for the Commission, details being given in the separate Farm Reports.

Mickleover and Hemsworth.

The *Mickleover* and *Hemsworth* farms afford instances of sewage treatment on *very shallow surface soils overlying stiff clay, i.e.*, on types of soil not well adapted for the treatment of sewage. But even under such unfavourable conditions the Mickleover effluents furnish an illustration of the point emphasised in the General Report, viz., that (the question of) purification by a soil is one of degree rather than one of intrinsic ability or disability.

Worsley.

The *Worsley* farm effluents from that portion of the farm which consisted of pure *peat* land were, as might have been expected, far from satisfactory, though even here there was a very considerable degree of purification. Without at all recommending

peat land for the treatment of sewage, it is interesting in this connection to recall a laboratory experiment made by the Rivers Pollution Commission (Vol. I., 1st Report, p. 69), as follows :—

> "These analytical results show that, although the action of the Lancashire "peat upon sewage is for a couple of months but slight and unsatisfactory, yet "the subsequent steady improvement of the effluent water encourages the hope "that this material would, after a somewhat longer education, become an "efficient purifier of sewage filtered through it at the rate of 49 gallons per cubic "yard, per 24 hours."

Luton.

Cities and towns such as Winchester and Luton, whose sewage farms are on the *chalk*, find themselves in the fortunate position of being untroubled by effluents, for the sewage at these places sinks into the ground and disappears. For this reason, attention may be drawn for a moment to the effluents obtained artificially by the filtration of the Luton sewage through different thicknesses of chalk *in situ, with previous removal of the surface soil.* The results of the chemical analyses showed that the sewage underwent comparatively little *direct* purification in its *rapid* passage through 3 feet of chalk. This emphasises the necessity for the careful examination of all well and spring waters which could by any possibility come within the sphere of influence of a chalk sewage farm.

Dr. Poore's Village System of Sewage Disposal.

Two visits were paid to Andover in connection with the interesting experiments on village sewage disposal which have now been carried out by Dr. Poore for a number of years. The short notes of these visits, with the analytical results, will be found in the Engineering, Bacteriological and Chemical Reports respectively.

Filtration v. Surface Irrigation Effluents.

The foregoing results show how difficult it is to generalize here, or to say dogmatically that one of those classes of effluent is better than the other, seeing that the soils in both types of farms differ so much in quality. To put the matter broadly, one may say that the best effluents are to be obtained by filtration through such soil and subsoil as those at Nottingham, the land being cropped. It is very improbable that any irrigation farm dealing with a reasonable quantity of sewage could produce such effluents. At the same time an irrigation farm on good soil, such as that at Beddington, can also yield very excellent results. The irrigation effluents from heavy soils cannot be expected to reach the highest standard, though even here fair results can be obtained by a proper regulation of the dose of sewage, and effluents either free or practically free from suspended solids produced; whether such effluents would ever be colourless, like the best filtration effluents, is doubtful. The sometimes large quantity of very flocculent (and therefore very light) matter that may be brought down from the drain pipes by filtration effluents is a point that merits attention. Judging from the earlier samples at Nottingham, these flocculent solids need not be present if the land is suitable, and if the volume of sewage treated is moderate in amount.

Influence of season upon the chemical quality of effluents.

So far as our results go, the quality of the various effluents from the different farms did not vary very materially at different times of the year, though in summer and early autumn the effluents were necessarily more concentrated than during the colder months. On the whole they were not quite so good in the warm seasons. This point should in future be tested systematically by the rate of absorption of dissolved oxygen (*see* sub-section dealing with Chemical Standards of Purity for Sewage Effluents, page 325).

TABLE A.—TABLE OF AVERAGE FIGURES SHOWING THE

NAME OF FARM. Number of Samples of Sewage Examined.	ALTRINCHAM. 4 Chance samples of sewage and 5 of lagoon liquor.	ALDERSHOT CAMP. 9 Chance samples and 3 sets of hourly samples.	CROYDON (BEDDINGTON). * 5 to 7 Chance and 7 sets of hourly samples.
Parts per 100,000 *by weight.*	Average.	Average.	Average.
Total nitrogen :—Chance samples.	2·06 to 5·01=**3·56**	12·45 to 24·89=**17·6**	6·82 to 13·42=**9·50**
Hourly samples.	—	12·31 to 14·24=**13·3**	6·42 to 7·59=**7·18**
Ammoniacal nitrogen : — Chance samples.	0·69 to 3·69=**2·29**	8·26 to 16·94=**12·30**	4·15 to 9·71=**7·34**
Hourly samples.	—	7·60 to 8·21=**7·87**	4·18 to 5·11=**4·50**
Total organic nitrogen : — Chance samples.	0·69 to 3·69=**2·29**	3·39 to 9·10=**5·35**	2·03 to 4·06=**3·37**
Hourly samples.	—	4·25 to 6·18=**5·06**	1·31 to 2·88=**2·07**
Albuminoid nitrogen : — Chance samples.	0·20 to 1·14=**0·62**	2·05 to 3·63=**2·77**	0·99 to 2·36=**1·72**
Hourly samples.	—	1·54 to 1·69=**1·62**	0·59 to 1·12=**0·91**
"Oxygen absorbed" from permanganate at 26·7° C. (80° F.) *in four hours* :—Chance samples.	2·29 to 6·98=**5·22**	20·68 to 38·47=**25·94**	7·91 to 18·73=**13·70**
Hourly samples.	—	19·54 to 22·40=**20·79**	7·85 to 17·45=**12·48**
Chlorine :—Chance samples.	7·22 to 12·88=**9·43**	8·90 (?) to 13·98=**11·38**	5·70 to 10·50=**8·15**
Hourly samples.	—	11·36 to 19·78=**14·98**	7·86 to 9·22=**8·34**
Solids in Suspension (gravimetrically) :—Hourly samples.	—	32·0 to 39·8=**36·6**	21·2 to 53·0=**34·5**
"Cellulose" in Solids in Suspension :—Hourly samples.	—	9·0 to 12·68=**10·79**	—
Parts per 100,000 *by Volume.*			
Solids in Suspension, as determined by Centrifuge :—Chance samples†	27 to 99=**72** 2 sewages and 3 lagoon liquors.	—	—
Hourly samples.†	—	148 to 216=**173**	173 to 356=**218**
*Ratio of Solids in Suspension to Centrifuge solids : — Hourly samples.	—	1 : 3·9 to 1 : 5·4 =**1 : 4·7**	1 : 4·8 to 1 : 8·2 =**1 : 6·6**
Ratio of "Celluloses" to Suspended Solids (grav.) :—Hourly samples.	—	1 : 8·1 to 1 : 11·2 =**1 : 9·7**	1 : 3·6 to 1 : 6·2 =**1 : 4·8**
**Note.*—This is a comparison of a figure expressing weight with one expressing volume.			

* Some of the samples were subjected to more tests than others.
† These figures express the *volumes* of the muds.

Chemical Composition of the different Sewages.

Cambridge. 5 Chance samples and 3 sets of hourly samples.	Leicester. 5 Chance samples and 3 sets of hourly samples.	Nottingham. 4 Chance and 3 sets of hourly samples.	Rugby. 8 Chance samples and 3 sets of hourly samples.	South Norwood. 4 to 7 Chance and 7 sets of hourly samples.
Average.	Average.	Average.	Average.	Average.
1·50 to 11·52=**3·94**	2·90 to 8·61=**5·57**	4·68 to 7·86=**6·39**	2·80 to 14·94=**9·95**	3·52 to 10·84=**7·07**
5·60 to 5·80=**5·71**	7·32 to 9·16=**8·12**	7·53 to 7·82=**7·69**	9·39 to 9·99=**9·65**	4·46 to 5·63=**5·20**
0·89 to 7·31=**2·41**	2·90 to 8·61=**5·57**	3·21 to 5·32=**3·92**	1·95 to 11·21=**7·37**	5·35 to 7·60=**6·50**
3·77 to 3·85=**3·82**	7·32 to 9·16=**8·12**	3·08 to 4·53=**3·98**	5·74 to 6·46=**6·11**	3·15 to 4·05=**3·54**
0·39 to 4·09=**1·29***	1·18 to 2·41=**1·68***	1·47 to 4·24=**2·42***	1·61 to 5·57=**2·54**	2·04 to 3·24=**2·55**
1·73 to 1·95=**1·88**	2·10 to 2·53=**2·34**	2·56 to 4·21=**3·15**	2·87 to 3·55=**3·29**	1·02 to 1·90=**1·49**
0·28 to 1·52=**0·62**	0·66 to 1·70=**1·11**	1·18 to 2·63=**1·77**	0·40 to 2·84=**1·49**	0·98 to 1·23=**1·07**
0·89 to 0·96=**0·91**	0·97 to 1·44=**1·19**	1·17 to 1·99=**1·45**	1·56 to 1·80=**1·73**	0·55 to 1·04=**0·67**
2·07 to 17·81=**6·99**	7·77 to 16·41=**12·45**	10·97 to 25·06=**17·64**	3·55 to 33·31=**15·0**	6·74 to 20·08=**11·40**
9·49 to 10·68=**10·08**	20·28 to 24·83=**22·35**	21·03 to 26·29=**23·12**	17·55 to 19·18=**18·44**	5·43 to 9·77=**7·71**
4·95 to 10·30=**6·37**	3·51 to 11·94=**8·10**	9·66 to 23·42=**16·35**	4·86 to 18·30=**11·68**	7·28 to 8·88=**7·87**
7·90 to 8·74=**8·45**	12·50 to 13·84=**13·38**	11·25 to 15·36=**13·68**	9·36 to 10·46=**9·99**	7·08 to 8·00=**7·45**
23·8 to 28·6=**26·5**	33·6 to 34·8=**34·1**	34·4 to 79·2=**51·9**†	43·0 to 50·6=**47·3**	9·6 to 38·2=**21·9**
3·84 to 5·08=**4·48**	6·56 and 5·80=**6·18**	5·32 to 15·08=**8·88**†	5·88 to 7·92=**7·22**	—
—	—	—	—	—
146 to 176=**160**	160 to 261=**196**	—	258 to 345=**304**	80 to 245=**139**
1 : 5·5 to 1 : 6·5 =**1 : 6·0**	1 : 4·8 to 1 : 7·5 =**1 : 5·8**	—	1 : 6·0 to 1 : 7·1 =**1 : 6·4**	1 : 4·7 to 1 : 9·1 =**1 : 6·6**
1 : 5·6 to 1 : 6·2 =**1 : 5·9**	1 : 5·3 to 1 : 5·8 =**1 : 5·6**	1 : 5·3 to 1 : 6·7 =**1 : 6·2**	1 : 6·1 to 1 : 7·3 =**1 : 6·6**	—
* This figure is possibly too low.	* This figure is possibly too low.	* This figure is probably too low. † These figures are probably higher than the normal.		

TABLE B.—TABLE WITH SOME OF THE AVERAGE FIGURES SHOWING

NAME OF FARM.	ALTRINCHAM.	ALDERSHOT CAMP.	CROYDON (BEDDINGTON.)
Number of samples of effluents examined.*	14 to 16	16 to 18	15 to 16 (Of the final effluents two were over 2 fields only.)
Parts per 100,000 *by weight.*	Average.	Average.	Average.
Total nitrogen - - - -	1·36 to 4·99=**2·22**	3·69 to 8·99=**6·0**	1·02 to 3·49=**2·20**
Ammoniacal nitrogen - -	0·65 to 1·87=**1·23**	0·91 to 4·98=**1·85**	0·23 to 3·10=**1·48**
Albuminoid nitrogen - - -	0·07 to 0·25=**0·13**	0·12 to 0·47=**0·26**	0·06 to 0·23=**0·14**
Total organic nitrogen - - -	0·10 (?) to 0·45=**0·26**	—	0·09 to 0·55=**0·26**
Nitric + nitrous nitrogen - -	0·0 to 3·64=**0·76**	0·0 (?) to 5·97=**3·21**	0·03 to 1·43=**0·37**
"Oxygen absorbed" from permanganate at 26·7°C. (80°F.) *in four hours.*	0·92 to 2·65=**1·75**	1·02 to 5·68=**2·72**	0·90 to 2·09=**1·41**
Incubator test (as judged by smell)-	**81**% passed (16 samples tested.)	**89**% passed (18 samples tested.)	**73**% passed (15 samples tested.)

* Some of the effluents were subjected to more tests than others.

TABLE C.—TABLE SHOWING APPROXIMATELY THE PERCENTAGE CHEMICAL PURIFICA-ON (a) ALBUMINOID NITROGEN AND (b)

NAME OF FARM.	ALTRINCHAM.	ALDERSHOT CAMP.	CROYDON (BEDDINGTON).
(a) Calculated on Albuminoid nitrogen;	**79**%* On Chance samples of sewages and lagoon liquors together.	**94**% on Chance samples. **84**% on Hourly samples of sewage.	**92**% on Chance samples. **89**% on Hourly samples.
(b) Calculated on "Oxygen absorbed" from permanganate at 26·7°C. (80° F.) *in four hours.*	**67**%*	**90**% on Chance samples. **87**% on Hourly samples of sewage.	**90**% on Chance samples. **89**% on Hourly samples.

*This calculation is very approximate and of doubtful value.

THE CHEMICAL COMPOSITION OF THE DIFFERENT FINAL AND GENERAL EFFLUENTS.

CAMBRIDGE.	LEICESTER.	NOTTINGHAM.	RUGBY.	SOUTH NORWOOD.
17 to 18	8 to 13	13	16 to 19	11 effluents (total nitrogen and "oxygen absorbed"); 6 effluents (ammoniacal and albuminoid nitrogen). These include three 2-field effluents.
Average.	Average.	Average.	Average.	Average.
1·48 to 3·19=**2·09**	1·84 to 3·64=**2·53**	1·41 to 3·45=**2·27**	1·39 to 2·96=**2·31**	0·55 to 2·83=**2·30**
0·22 to 1·31=**0·65**	0·59 to 2·81=**1·65**	0·01 to 0·29=**0·13**	0·97 to 2·81=**1·62**	0·02 to 1·55=**0·87**
0·04 to 0·18=**0·09**	0·07 to 0·35=**0·20**	0·01 to 0·10=**0·03**	0·08 to 0·39=**0·18**	0·07 to 0·14=**0·10**
0·04 (?) to 0·42=**0·21**	0·18 to 0·63=**0·45**	—	—	—
0·69 to 2·25=**1·26**	0·0 to 1·73=**0·51**	1·25 to 3·29=**2·06** and 1·24 to 1·71 in four later samples.	0·0 to 1·59=**0·52**	0·14 to 0·74 (?)=**0·39**
0·16 to 1·31=**0·81**	1·70 to 4·47=**2·50**	0·05 to 0·37=**0·19**	0·72 to 2·16=**1·41**	0·97 to 1·73=**1·44**
94% passed (18 samples tested.)	**92**% passed (13 samples tested.)	**100**% passed (17 samples tested.)	**75**% passed (20 samples tested.)	**75**% passed (12 samples tested.)

TION ON THE VARIOUS SEWAGES EFFECTED AT THE DIFFERENT FARMS, AS CALCULATED "OXYGEN ABSORBED" FROM PERMANGANATE.

CAMBRIDGE.	LEICESTER.	NOTTINGHAM.	RUGBY.	SOUTH NORWOOD.
85% on Chance samples.	**82**% on Chance samples.	**99**% on Chance samples.	**88**% on Chance samples.	**91**% on Chance samples.
90% on Hourly samples.	**85**% on Hourly samples.	**98**% on Hourly samples.	**89**% on Hourly samples.	**85**% on Hourly samples.
88% on Chance samples.	**80**% on Chance samples.	**99**% on Chance samples.	**91**% on Chance samples.	**87**% on Chance samples.
92% on Hourly samples.	**88**% on Hourly samples.	**99**% on Hourly samples.	**92**% on Hourly samples.	**81**% on Hourly samples.

Sewages and Effluents.—Some Average Ratios of Analytical Figures.

It may not be without interest if some of the approximate average ratios of the figures of analysis which have been worked out for the sewages and effluents are given here. At the same time it should be steadily borne in mind that although, *on the average*, the figures for any two determinations (say, determinations of albuminoid nitrogen and "oxygen absorbed") may yield a fairly constant ratio, the ratios in individual samples may yet vary within such wide limits as to preclude any idea of one test being used as a substitute for another.

(A.) Sewages.

If the curves of analysis of the hourly sewage samples from the different farms be examined (Diagrams 1 and 2), it will be seen that the various nitrogen curves follow one another with, on the whole, great regularity, and that the chlorine curve also agrees fairly well with them in most cases. The "oxygen absorbed" curve shows much greater divergences. The agreement between the curves for "cellulose," suspended solids determined gravimetrically, and suspended solids determined volumetrically by the centrifuge is also good.

1. *Ratio between Organic Nitrogen and "Oxygen absorbed."*

——	Aldershot Camp.	Nottingham.*	Rugby.	Leicester.	Beddington.*	Cambridge.	South Norwood.
Chance Samples -	1 : 4·8	—	—	1 : 7·4	1 : 4·1	1 : 5·4	1 : 4·5
Hourly - - -	1 : 4·1	1 : 7·3	1 : 5·6	1 : 9·6	1 : 6·0	1 : 5·4	1 : 5·2

* The Nottingham sewage was partly crude. The Beddington sewage was screened.

In a domestic settled sewage, therefore, the *average* ratio of the figure for organic nitrogen to that of "oxygen absorbed" appears to vary more or less between 4 : 1 and 5 5 : 1. Where trade refuse is present in quantity, as at Nottingham and Leicester, the ratio goes up very much. Of course it must be remembered, with regard to the above ratio, that while it may be looked upon as representing an average, the ratios in individual samples may vary considerably, as can be seen by a reference to the different sewage diagrams.

2. *Ratio between Albuminoid Nitrogen and "Oxygen absorbed."*

——	Aldershot Camp.	Nottingham.	Rugby.	Leicester.	Beddington.	Cambridge.	South Norwood.	Altrincham.
Chance—								
Average -	1 : 9·9*	1 : 10·4	1 : 10·3†	1 : 11·9	1 : 8·9	1 : 10·7	1 : 13·0	1 : 9·5‡
Extremes -	6·8 & 11·6	5·9 & 14·2	7·0 & 17·9	8·4 & 16·3	4·6 & 12·8	7·4 & 13·5	9·8 & 16·3	5·1 & 15·2
Even or not -	Fairly even	Very uneven	Very uneven	Very uneven	Very uneven	Very uneven	Uneven	Very uneven
Hourly—								
Average -	1 : 12·9	1 : 16·6	1 : 10·9	1 : 19·0	1 : 13·7	1 : 11·0	1 : 11·3	—
Extremes -	11·5 & 14·5	13·2 & 18·6	10·3 & 11·3	17·2 & 20·9	10·7 & 18·4	10·6 & 11·3	8·0 & 15·7	—
Even or not -	Fairly even	Uneven	Very even	Even	Uneven	Very even	Uneven	—

* Excluding one sample of crude.
† Partly crude, partly settled and partly precipitated.
‡ Sewages and lagoon liquors together.

From the above figures it would appear that for a settled domestic sewage the *average* ratio of albuminoid nitrogen to "oxygen absorbed" is somewhere about (10 to 13) : 1, but that the ratios in individual cases are very uneven. This has of course been observed before. The influence of the trade effluents in the Nottingham and Leicester sewages is again noticeable here. Possibly the facts of there being no settlement (only screening) at Beddington, and of peppermint being present in some of the samples, had something to do with the irregularity there.

(3) *Average Ratio of Total Organic Nitrogen to Total Nitrogen.*

Aldershot Camp.	Nottingham.	Rugby.	Leicester.	Beddington.	Cambridge.	South Norwood.
1 : 2·6*	1 : 2·6*	1 : 3·0*	1 : 3·5*	1 : 3·6* 1 : 3·1†	1 : 3·0*	1 : 3·6* 1 : 2·5†

* Hourly samples. (In the case of Nottingham one of the samples was abnormal, and reduced this average.)
† Chance and hourly samples taken together.

The *average* ratio of the Total Organic Nitrogen to the Total Nitrogen is therefore about 1 : 3, the extreme *average* figures in the above table being 1 : 2·5 and 1 : 3·5.

(4) *Average Ratio of Albuminoid Nitrogen to Total Nitrogen.*

Aldershot Camp.	Nottingham.	Rugby.	Leicester.	Beddington.	Cambridge.	South Norwood.
1 : 8·2*	1 : 5·6*	1 : 5·6*	1 : 6·8*	1 : 8·2* 1 : 6·3†	1 : 6·3*	1 : 7·7* 1 : 7·0†

* Hourly samples.
† Chance and hourly samples taken together.

Here the variations are more marked than in the case of the organic nitrogen; but an average figure appears to be somewhere about 1 : 7.

(5) *Average Ratio of Albuminoid Nitrogen to Total Organic Nitrogen.*

Aldershot Camp.	Nottingham.	Rugby.	Leicester.	Beddington.	Cambridge.	South Norwood.
1 : 3·1*	1 : 2·2*	1 : 1·9*	1 : 1·9*	1 : 2·3* 1 : 2·1†	1 : 2·1*	1 : 2·1* 1 : 2·8†

* Hourly samples.
† Chance and hourly samples taken together.

Speaking *roughly*, the *average* Total Organic Nitrogen in the above sewages is about double the Albuminoid Nitrogen. This is brought out more clearly in the curves of the hourly sewage samples.

6. *Suspended Solids in the Sewages as run on to the Land* (*parts per* 100,000).

——	Aldershot Camp.	Notting-ham.	Rugby.	Leicester.	Beddington.	Cambridge.	South Norwood.
Hourly samples - - -	36·6	51·9	47·3	34·1	34·5	26·5	21·9

In no case, therefore, was there a very great settlement before the sewage was treated.

7. *Ratio of the average figures expressing Gravimetric Solids* (*weights*) *to those for Centrifuge Solids* (*volumes*).

——	Aldershot Camp.	Notting-ham.	Rugby.	Leicester.	Beddington.	Cambridge.	South Norwood.
Hourly samples - - -	1 : 4·7	—	1 : 6·4	1 : 5·8	1 : 6·6	1 : 6·0	1 : 6·6

It will thus be seen that in all the above sewages, excluding the very strong sewage at Aldershot Camp (where the solids appear to have been rather heavier),

the *average* ratio of gravimetric solids to "centrifuge* solids" is in every case about 1 : (6 to 7). Strictly speaking, it is illogical to compare a figure expressing volume with one that expresses weight, but it is worth while doing so in this instance.

8. *Ratio between the average figures for "Celluloses"‡ and Suspended Solids.*

——	Aldershot Camp.	Nottingham.	Rugby.	Leicester.	Beddington.	Cambridge.	South Norwood.
Hourly samples - - -	1 : 9·7	1 : 6·2	1 : 6·6	1 : 5·6	—	1 : 5·9	—

If we again except the sewage at Aldershot Camp, in which the preponderance of other solids to cellulose is very marked, the above figures indicate that the "cellulose" in a settled† sewage constitutes *roughly* one-sixth by weight of the total solids in suspension in that sewage.

Relation between Chlorine and Ammoniacal Nitrogen.—A study of the curves of the sets of hourly sewage samples shows that in the domestic sewages the chlorine curve follows that for ammoniacal nitrogen very evenly, but that there is no relation between it and the "oxygen absorbed" curve. In an average set of hourly samples of a domestic sewage, therefore, the amount of chlorine might be taken as a rough guide to the ammoniacal strength of the sewage (this being, in fact, frequently done), but in chance samples it might not infrequently be misleading.

(B) Final and General Effluents.

The numerous analyses of effluents given in the Tables of Analysis referring to the different farms also show that though, *on an average*, the ratio between one test and another, stated numerically, may work out very evenly, the individual variations may be great. Hence there is considerable danger in reducing too far the number of chemical tests to be applied to an effluent, if an accurate estimate of its character is to be formed.

The following ratios may be found of some interest :—

(1) *Ratio between Albuminoid Nitrogen and "Oxygen Absorbed"*

(after deducting from the "oxygen absorbed" the oxygen equivalent of the nitrite present).

——	Nottingham.	Cambridge.	Altrincham.	Beddington.	Aldershot Camp.	Rugby.	Leicester.	South Norwood.
Ratio - -	1 : 7	1 : 8	1 : 14	1 : 10	1 : 11	1 : 8	1 : 14	1 : 14
Limits - -	1:2 & 1:12	1:4 & 1:11	1:7 & 1:22	1:8 & 1:16	1:5 & 1:19	1:6 & 1:10	1:7 & 1:18	1:10 & 1:19
Average ratio for the eight farms, 1 : 11.								
Number of effluents tested	13	16	16	14	17	16	9	5

The above ratio is of special interest, because of those two tests being so frequently relied upon for determining the quality of an effluent. It will be seen from the figures that in the case of Nottingham, Altrincham, Aldershot Camp and Leicester, the ratios are very uneven, but that they are fairly even—within rather wide limits—in the case of South Norwood, Cambridge, Rugby and Beddington. In no instance, however, could the one test have been taken as a substitute for the other. Speaking generally, the better effluents have the lower ratios, though this is not by

* *Note.*—The volume given by the centrifuge is of course not the volume of the solids alone, but the volume of the mud (solids + water) deposited in the narrow calibrated part of the tube.

† *Note.* The Nottingham sewage was a mixture of screened + crude.

‡ *Cf.* p. 3, par. 8; also Report on Methods of Chemical Analysis (Part V.).

any means always the case. Again, with exceptionally good effluents like those from Nottingham this very approximate conclusion may not hold, because of the error of experiment in the *small* "oxygen absorbed" figure being relatively great.

Note.—Some comparative quantitative laboratory experiments have shown—as was to be expected—that the oxidation by the *alkaline* permanganate solution used in the determination of albuminoid nitrogen at a high temperature (100° C. or *over*) is much greater than that effected by the acid permanganate solution employed for the "oxygen absorbed" test at much lower temperature (26·7° C.).

(2) *Average Figures obtained for Total Nitrogen, Total Organic Nitrogen and Albuminoid Nitrogen.*

Average.	Nottingham.	Cambridge.	Altrincham.	Beddington.	Aldershot Camp.	Rugby.	Leicester.	South Norwood.
Total Nitrogen.	2·30	2·09	2·22	2·20	6·0	2·31	2·53	2·30
Total Organic Nitrogen.	—	0·21	0·26	0·26	—	—	0·45	—
Albuminoid Nitrogen.	0·03	0·09	0·13	0·14	0·26	0·18	0·20	0·10

(1) If we leave out of account the highly nitrated effluent from the strong sewage at Aldershot Camp, it is very remarkable that the *average figures* for total nitrogen in the effluents from the other seven farms only vary within the narrow limits of 2·09 and 2·53.

(2) There is naturally no relation between the figures for total nitrogen on the one hand, and those for total organic and albuminoid nitrogen on the other, seeing that the degree of oxidation of the different farm effluents varied considerably.

(3) In the case of Cambridge, Altrincham, Beddington and Leicester, the *average* albuminoid nitrogen in the effluents constituted almost exactly one-half of the *average* total organic nitrogen; the data in the case of the other four farms are insufficient.

(3) (A.) "*Safety*" *Ratio between Oxidized and Unoxidized Nitrogen* (*Unoxidized* = 1).

(B.) "*Safety*" *Ratio between Albuminoid and Oxidized Nitrogen* (*Albuminoid* = 1).

—	Nottingham.	Cambridge.	Altrincham.	Beddington.	Aldershot Camp.	Rugby.	Leicester.	South Norwood.
(A) - - - -	?	1:1 or 1·5:1	0·5 : 1	Probably medium.	0·3 or 0·6 : 1	Probably 0·25 : 1	0·5 or 1·0 : 1	Probably somewhat high.
(B) - - -	?	Probably high.	3 : 1	Probably 3 : 1	Say 4 : 1	Probably 2 : 1	About 1·5 : 1	Probably somewhat high.

By (A) is meant the minimum ratio of oxidized (nitric + nitrous) nitrogen to total unoxidized nitrogen, which allows an effluent to keep sweet upon incubation. The figures, however, are less conclusive than some of the others, but they show clearly that this ratio varies very considerably in different types of effluents.*

(B) The "safety" ratio of oxidized to albuminoid nitrogen is, perhaps, more easy of application. With the exception of the Cambridge effluents, which appeared to require a somewhat high ratio—*i.e.*, a *relatively* large reserve of nitrate—none of the others were higher than 3 : 1 or 4 : 1.* (Compare sections dealing with (*a*) artificial storm waters, and (*b*) standards.)

Notes.—(*a*) The Nottingham effluents were of such a high class that no approximation can be given here.
(*b*) The data from South Norwood are insufficient for generalisation; probably, however, the "safety" ratio between oxidized and albuminoid nitrogen would be rather high in this case, seeing that the effluent is one from a dilute sewage.

* No account has been taken here of the dissolved oxygen present in the effluents; this ought to be done.

Brook and River Waters, into which Sewage Effluents flow.

In his *General Bacteriological Conclusions* on the Land treatment of Sewage (Part III.: Bacteriological Report) Dr. Houston has brought forward strong arguments to show that no brook or river into which an effluent from a sewage farm flows should be used as a source for drinking water. *In what follows, therefore, the streams are regarded from the point of view of non-drinking waters.*

Fifty-four samples* in all of brook or river water from the various farms, drawn either above the effluent outfall or below it, were examined, some of them in duplicate after being kept for a time; this is, of course, not a very large number from which to deduce general conclusions, and any remarks made with regard to the brooks or rivers must therefore be read subject to this proviso. The details of the analyses are to be found in the separate Farm Reports.

1. *Aldershot Camp Farm; River Blackwater.* Normal ratio of farm effluent to river water, 1 : 6.

This small river was not in a satisfactory state at the times when our observations were made, more especially during summer, but this was due to polluting matter entering it above the farm. The Aldershot Camp farm effluent from the old land must have exercised an oxidizing effect on the organic matter already present in the water. At the same time attention should again be called to the rather considerable bulk of fine flocculent weed (from the drain pipes) which is carried into the stream along with the effluent, and also to the high manurial value of the effluent itself. Not only is there a great loss of nitrate and other manurial constituents here, but the effluent must tend to choke the stream indirectly by encouraging vegetable growth in it.

2. *Altrincham Farm; Sinderland brook.* Normal ratio of effluent to brook water, 1 : 3.

Like the Blackwater, the Sinderland brook was polluted before it reached the Altrincham farm (speaking generally, the farm effluent must have had an oxidizing effect upon it), and was not in a satisfactory state at the time when our observations were made.

3. *Cambridge; River Cam.* Normal ratio of effluent to river water, 1 : 15.

At Cambridge the river was in a fair condition in January and February, 1901. Of course the comparatively large volume of river water here minimises any effect that the effluent may exert upon it.

4. *Croydon (Beddington); River Wandle.* Normal ratio of effluent to river water, 1 : 8; ratio at first time of sampling, 1 : 12.

Judged by a non-drinking water standard, little or no fault was on the whole to be found with the water of the River Wandle in February and October, 1900, though the samples examined were not altogether free from flocculent matter. Here again we have a comparatively large volume of river water as compared with that of effluent. The last six samples were incubated before being examined, and, even allowing for the fact of the standard copper chloride tubes having weakened somewhat, the samples maintained their dissolved oxygen well (*i.e.*, for a *non*-drinking water stream).

---

* These were:—
River Blackwater, seven samples (five in duplicate);
Sinderland Brook, six samples (one in duplicate);
River Cam, five samples (two in duplicate);
River Wandle, nine samples;
Anstey Brook, six samples;
River Trent, five samples (two in duplicate);
River Avon, eight samples (three in duplicate);
Chaffinch Beck, four samples;
Parrin Brook, four samples.

5. *Leicester; the Anstey brook.* Ratio of effluent to brook water at time of sampling 1 : 1.

The volume of water in this small brook is sometimes less than that of the combined effluents from the farm in summer, but the flow is fairly rapid; in the Engineering Report reference is made to the green growths in the stream, no sewage weed being observable. The samples tested varied somewhat, as was to be expected with such a small flow of water, and they contained appreciable amounts of suspended solids, no doubt from the effluent drain pipes; but, taking the existing circumstances of small dilution into account, the condition of the brook might be regarded as fairly satisfactory from a chemical point of view.

6. *Nottingham; the Trent.* Ratio of farm effluent to river water, say 1 : 160; the variations in volume are great, but the minimum ratio is about 1 : 60.

In the months of July and August, 1900, the water of the Trent, as it flowed past the Nottingham farm, was not at all of high quality, though there was nothing offensive about it; it contained for a river water a large proportion of oxidizable matter, and usually a considerable quantity of solids in suspension. The volume of effluent as compared with that of the river water is very small, but, so far as it goes, the effluent must exercise an oxidizing effect on the water of the river, which—as stated in the Engineering Report—receives the sewage from most of the populous villages on its banks.

7. *Rugby; the Avon.* Normal ratio of farm effluent to river water, 1 : 20; ratio at second time of sampling, 1 : 30.

The water of this river was, on the whole, in fair condition chemically, at the time of our observations, but in summer the large amount of oxidizable matter in one of the samples drawn above the effluent outfall showed that there was at the time some polluting liquid—not from the high level farm—entering the river. Still, the samples tested maintained their oxygen fairly well upon incubation. The volume of river water to effluent is again rather large here.

8. *South Norwood; the Chaffinch Beck.* Ratio of effluent to brook water at second time of sampling, 3 : 1.

Even in winter the volume of this little stream often does not exceed that of the farm effluent, while the Engineering Report states that in dry seasons very little effluent leaves the farm at all, owing to evaporation. It is further noted in that Report that the Beck evidently receives a certain amount of pollution from surface water drains which join the effluent ditch before the effluent itself flows into the brook. The samples of water examined contained very appreciable amounts of brownish flocculent matter in suspension and showed too much oxidizable matter generally. There was no question of nuisance arising, and three out of the four samples were well aerated when analysed, but the relatively high figures for "oxygen absorbed" from permanganate showed that, from one cause or another, this little brook—judged from a brook-water standard—was not in a very satisfactory condition at the time our few observations were made.

9. *Worsley; The Parrin brook.*

This brook, which is of small volume, was in a very unsatisfactory state when our samples were drawn and examined. It is however noted in the Engineering Report that the contamination of the water arose not merely from the effluent of the Worsley farm, but also from that of another sewage farm higher up the stream.

Conclusion.

It will thus be seen that the rivers or brooks at about half of the above farms were not in a satisfactory condition, but that in nearly every one of these cases the material pollution took place *above* the farm effluent outfalls, *i.e.*, the streams were polluted before they arrived at the farms. Leaving out the contingency of having

a sewage farm on peat or other wholly unsuitable land, *assuming always that the water not to be used for drinking or domestic purposes*, and speaking in general terms, there seems no reason why the purity of a brook or river should be so affected by the discharge of an effluent from a well-managed sewage farm as either to give rise to any nuisance, or, so far as can be judged in the present state of our knowledge, to injure fish life.

Subsoil Waters.

Of subsoil, well and spring waters, drawn in the immediate neighbourhood of sewage farms, 15 samples were analysed, viz. :—

No. 5, Leicester subsoil water;
,, 60, Aldershot Camp well water;
,, 78, Altrincham subsoil water;
,, 219, Cambridge subsoil water;
,, 227, ,, 239, } Rugby well water;
,, 242, ,, 244, ,, 410, } Luton well water;
,, 240, ,, 241, ,, 243, } Luton spring water;
,, 279, ,, 283, ,, 290, } Water from unsewaged peat land on the Worsley farm.

For the details of the analyses of these, the separate Farm Reports with their accompanying Tables must be consulted, but a short summary may be given here.

Leicester.—No. 5 was a sample of subsoil water drawn from a small sandy stratum in the boulder clay, at a depth of 7 feet 6 inches, from a high-lying portion of the Leicester farm; this part of the farm, although it had never been actually sewaged itself, was within 50 yards of sewaged ground. The sample proved to be a very pure water organically, with no signs of sewage contamination, chemically speaking.

Aldershot Camp.—No. 60, a sample of well water representing the subsoil water, was drawn far enough away from the farm to be in no danger of contamination. The well was 8 feet 6 inches deep, and there were 3 feet 6 inches of water in it at the time. This water was fairly pure, though it yielded too much albuminoid nitrogen for a drinking water, and it also contained a relatively large amount of organic matter—evidently of vegetable origin.

Altrincham.—No. 78 was a sample of subsoil water, drawn from a trench on the farm sunk 3 feet 6 inches deep; this trench was about 150 yards from the sewaged land and about 100 yards from a large heap of fish refuse. The sample might be classed organically as a moderately good effluent, the high "oxygen absorbed" figure being to some extent due to the presence of ferrous iron. The water, coming as it did from peat land, remained distinctly acid after being boiled.

Cambridge.—No. 219, subsoil water taken at the outcrop of the Gault from a land drain. This water was very pure, though showing rather too much albuminoid nitrogen for a drinking water. It contained practically no oxidizable matter, the dissolved oxygen undergoing hardly any diminution in a duplicate sample kept for two months at atmospheric temperature; there was a considerable amount of nitrate in it.

Rugby.—Nos. 237 and 239 were interesting samples, drawn from a well on the High Level farm at Rugby which was within 40 feet of sewaged land. The well was 20 feet deep, with 10 feet of water in it. Both samples were organically pure, although the large amounts of chlorine and of nitric nitrogen present showed that the water must in all probability have been derived from the sewage of the farm, which had however undergone in its passage through the soil a most efficient filtration and purification, chemically speaking.

Luton.—(*a*) Nos. 242, 244 and 410 were samples of water drawn from a well in a cottage garden about 90 yards from the Low Level sewage farm. The well was 20 feet deep, with 2 feet and 1 foot 3 inches of water in it at the different times. These samples showed pollution, but the results were inconclusive as regards the sewage farm, for it was found in the course of the examination that the well was liable to pollution from fæcal matter applied as manure in its immediate neighbourhood.

(*b*) Nos. 240, 241 and 243 were samples of spring water drawn from springs at some watercress beds about 200 yards from the Luton Low Level sewage farm. This water proved to be good chemically, though No. 243 did not maintain its dissolved oxygen very well on incubation, thus showing the presence of a little oxidizable matter of one kind or another. The variation in the amount of chlorine in Nos. 240 and 243, both of which were drawn from the same spot within eight days of one another, also requires elucidation.

Worsley.—Nos. 279, 283 and 290 were samples of peat water drawn from the unsewaged part of the peat land on the Worsley farm. The first and last of these were apparently free from sewage contamination, and they showed the usual characteristics of peaty waters, *i.e.*, they contained a good deal of oxidizable organic matter and remained acid even after being boiled.

With so few samples, drawn under such diverse conditions, it would be unwise to attempt any generalisation other than that the results show that very great care is necessary with respect to drinking water supplies drawn anywhere in the neighbourhood of a sewage farm.

Storm-Waters.

Only one sample of storm-water from a farm was examined, viz., No. 68, drawn at Altrincham after the overflow had been working for an hour and a-half. This was a dilute sewage, and putrid when received, though containing only a small quantity of black deposit. It gave the figures 0·48 albuminoid nitrogen, 0·93 total organic nitrogen, and 6·13 "oxygen absorbed" in 4 hours at 26·7° C. (80° F.).

Somewhat more recently, however, we have been enabled by the courtesy of Mr. Tatton, of the Mersey and Irwell Joint Committee, to examine about thirty samples of storm-water from Macclesfield, Rochdale and Stockport. So far, nearly all of these have been drawn on the ascending curve of the storm, the dilutions ranging between three and seven times the dry-weather flow,—in the majority of cases three to four times. In quality those storm-waters might be classed as varying between exceptionally strong and very weak sewages, nearly half of them being weak, and the remainder medium to strong. A few of them contained extraordinary amounts of suspended solids (up to 366 parts per 100,000), others only small quantities. When the samples came to be analysed, about two-thirds of them were more or less inoffensive as regards smell, the remaining third having a sewage odour. Fully half of them were subjected to the incubator test, with the result that they became putrid; and no doubt all the others would have done the same. In comparing sets of samples drawn on the same day, at intervals during the storm, it was seen that the liquid might continue to be bad during a flow of two or three hours; this is, of course, a point of great importance.

These results are sufficient to emphasize the necessity for settling and treating storm-waters up to the limit of dilution that a sewerage system may reasonably be asked to provide for (*cf.* Part I.: General Report, Section IX.—General Conclusions).

Surface Street Washings, &c.

Of *Surface Street Washings*, seven samples were examined, viz., Nos. 174, 179 182 and 187A from South Norwood; No. 231 from Rugby; and No. 311 and 314 from Aldershot Camp. The detailed analyses of these are given in the tables appended to the respective Farm Reports, but they may be shortly summarized here.

No. 174, drawn 14th November, 1900, was a sample of surface water from streets and front roofs drawn at South Norwood during sharp showers, the weather having been showery on the day previous. It contained a good deal of sand, but was comparatively pure as regards organic matter and kept good upon incubation.

No. 179, drawn 21st November, 1900, was another sample of surface water from streets, after moderate showers, the streets having been previously washed fairly clean by rain. This did not contain much sediment, but was organically more impure than the preceding sample; it had no smell when received, but became putrid upon incubation.

No. 182 was drawn on 28th November, 1900, after the surface drains had been running for three hours. It was very turbid and brown and contained much grit. Organically it might be classed as a dilute sewage.

No. 187A, street water drawn 1st December, 1900, after a slight rainfall, was comparatively pure as regards organic matter. Though it showed a good deal of flocculent sediment, it kept sweet upon incubation.

No. 231, street washings taken from a surface water drain at Rugby on 4th March, 1901, at a time when the street was very clean after heavy showers, was turbid and brown with a large amount of gritty sediment, but comparatively pure as regards organic matter; it withstood incubation.

No. 311, street washings from a surface water ditch at Aldershot, was drawn on 2nd July, 1901, after two days heavy rainfall; at the time of drawing, the water in this ditch was flowing at about the rate of ten million gallons per 24 hours. The above sample was brown and turbid (though it had only a slight brown tinge when filtered), and it contained a great deal of sand and also brownish suspended matter. The analysis gave the high figures of 0·49 parts albuminoid nitrogen, 1·05 total organic nitrogen and 8·93 "oxygen absorbed" in four hours. Though this had a clean smell when analysed, it became black and putrid upon incubation.

No. 314, street washings and roof water from Aldershot Camp, drawn 3rd July, 1901, after three days' rain, was muddy from a considerable quantity of suspended solids, with grit in addition. Though the aggregate organic matter was less than in sample No. 311 (the figures being 0·34 albuminoid nitrogen, 0·64 total organic nitrogen and 3·46 "oxygen absorbed"), it was smelling slightly when analysed and became black and putrid on incubation.

Although the above samples were few in number, they show at all events:—

1. That even when a street water is comparatively pure organically, it requires settlement for grit (Nos. 174 and 231).
2. That even after long-continued rain, street surface waters may be very impure (Nos. 182, 311 and 314).

Artificial Storm Waters.

The consideration of storm waters again raises the question of standards, and illustrates very clearly the weak points of what may be called an "absolute"* standard for effluents. In connection with this, the following experiments were done:—

(1) Six artificial storm waters were made at different times from Beddington and South Norwood sewages by diluting them down to (*a*) the Mersey and Irwell provisional effluent standard for albuminoid nitrogen (0·12 part per 100,000), or (*b*) to half that standard (0·06 part) with tap water; this latter of course contained dissolved oxygen, and, in addition, some nitrate.† These liquids (Nos. 158, 161, 164A, $164A_{(1)}$, 170, and $181A_{(2)}$) were then allowed to stand for six to twelve days in full bottles, either at laboratory temperature or at 26·7° C. (80° F.). In every case, excepting possibly No. $164A_{(1)}$ (the sample diluted to *half* the M. and I. standard), the mixture was eventually found to be putrid.

* The term "absolute" is not really distinctive, but it may serve for want of a better.

† Two samples of this tap water, examined at a later date, were found to contain approximately 0·25 and 0·30 parts of nitric nitrogen per 100,000.

Again, three other samples (Nos. $181_{A_{3,\,4,}}$ and $_5$) were diluted with tap water to the Mersey and Irwell effluent standard for albuminoid nitrogen, and quantities of potassic nitrate were added equal respectively to 0·1, 0·2 and 0·3 parts nitric nitrogen per 100,000 of liquid. After incubation at 26·7° C. (80° F.) for seven days, these were all found to be very putrid.

Lastly, three more samples (Nos. $193_{A_{2,\,3,}}$ and $_4$) were diluted with distilled water to the Mersey and Irwell effluent standard for albuminoid nitrogen, and quantities of ammonium nitrate were added equal to 0·3, 0·15 and 0·075 parts nitric nitrogen per 100,000, the last sample being then diluted further with three volumes of tap water. After incubation for six days all those three solutions were found to be sweet.

The results of the above experiments are thus to some extent contradictory, but, taken all over, they show :—

(1) That dilution of a sewage with tap water down to the Mersey and Irwell effluent standard for albuminoid nitrogen gives a mixture which putresces upon incubation. In other words such a mixture is far more liable to putrefaction than an effluent of apparently the same strength as judged by the albuminoid nitrogen test. Even when the dilution is carried twice as far—*i.e.*, down to half the Mersey and Irwell standard—the mixture will in all probability be putrescible upon incubation.

(2) That an added quantity of nitric nitrogen (up to 0·3 part per 100,000) to a dilute sewage of the Mersey and Irwell albuminoid nitrogen standard for effluents may not be sufficient to prevent this putrescence upon incubation, although on the other hand it may.

On the next page the foregoing results are given in tabular form.

For further notes and conclusions upon this point, see the Section upon Standards in this Report, page 325.

ARTIFICIAL STORM WATERS.

Made by diluting sewage with either tap water or distilled water down to—

(*a*) The Mersey and Irwell standard of albuminoid nitrogen - - - - - - (0·12 part per 100,000)
(*b*) Half - - - - - - - - - - - - - - - - - - (0·06 „ „)
(*c*) Quarter - - - - - - - - - - - - - - - - - (0·03 „ „)

In the last six samples also various quantities of nitric nitrogen were added, either as potassium or as ammonium nitrate.

No. Sample.	Farm.	Nature of Sewage.	Volume of Sewage taken. c.c.	Volume of Water added. c.c.	Tap* or Distilled Water.	Dissolved Oxygen in Water added (c.c. per litre).	Albuminoid Nitrogen in Mixture (parts per 100,000).	Length of time Incubated. Days.	Nitric Nitrogen* added.	Nitric + Nitrous Nitrogen found after Incubation.	"Oxygen absorbed" from Permanganate at 26·7° C. (80° F.) *at once* in		
											Original Dilution.	Portion Incubated at room temperature.	Portion Incubated at 26·7° C. (80° F.).
No. 158 - - -	Beddington -	Screened; strong -	20	380·6	Tap - -	Not determined -	0·12	about 8	—	—	0·20	0·37 {Strongly putrid.	0·50 {Strongly putrid.
„ 161 - - -	„ - -	Screened; rather weak	25	313	„ - -	„ -	0·12	11	—	—	0·13	0·09 Putrid.	0·23 Putrid.
„ 164A - - -	„ - -	„ „	100	737	„ - -	„ -	0·12	7	—	—	0·23	0·26 „	0·43 {Very putrid.
„ 164A(1) - -	„ - -	„ „	50	737	„ - -	„ -	0·06	7	—	—	0·14	0·14 „	0·17 {Sweet or doubtful.
„ 170(1) - -	South Norwood -	Crude; not very strong	20	366	„ - -	„ -	0·06	6	—	—	0·24	0·24 {Just putrid.	0·24 {Very putrid.
„ 181A(2) - -	„ „ -	Screened and settled; soapy; not very strong.	100	944	„ - -	„ -	0·12	12	—	—	0·19	—	1·20 {Very putrid.
„ 181A(3) - -	„ „ -	„ „	100	944	„ - -	„ -	0·12	12	0·10†	—	0·19	—	1·07 {Very putrid.
„ 181A(4) - -	„ „ -	„	100	944	„ - -	„ -	0·12	12	0·20†	—	0·19	—	0·65 {Very putrid.
„ 181A(5) - -	„ „ -	„ „	100	944	„ - -	„ -	0·12	12	0·30†	—	0·19	—	0·92 {Very putrid.
„ 193A(2) - -	„ „ -	Settled; rather dilute -	100	740	Distilled -	6·25	0·12	6	0·30†	0·13 {Sweet; earthy.	—	—	—
„ 193A(3) - -	„ „ -	„ „ -	100	740	„ -	6·25	0·12	6	0·15‡	0·13 {Sweet; earthy.	—	—	—
„ 193A(4) - -	„ „ -	„ „ -	25	740	„ -	6·25	0·03	6	0·075‡	0·06 Sweet.	—	—	—

* Two samples of tap water, examined at a later date, were found to contain approximately 0·25 and 0·30 parts nitric nitrogen per 100,000; the tap water used above was no doubt much the same as this.
† Added in the form of potassic nitrate.
‡ Added in the form of ammonium nitrate.

Chemical Standards of Purity for Sewage Effluents.

The question of what considerations should weigh most in recommending a working chemical standard of purity for sewage effluents is a very difficult one.

The standard of purity for effluents recommended by the Rivers Pollution Commission for 1868, so far as regards matter in suspension and organic matter in solution, is :—

(a) The liquid shall not contain, as solids *in suspension*, more than 3 parts by weight of dry mineral matter, or more than 1 part by weight of dry organic matter in 100,000 parts of effluent.

(b) It shall not contain *in solution* more than 2 parts by weight of organic carbon or more than ·3 part by weight of organic nitrogen per 100,000.*

The Mersey and Irwell Rivers Board *provisional* standard (converted into terms of nitrogen and into parts per 100,000) is :—

·12 part albuminoid nitrogen per 100,000*, and 1·43 parts "oxygen absorbed" from permanganate in 4 hours at 60° F. (15·6° C.). At the same time this Board also takes into account the rate at which an effluent takes up dissolved oxygen and nitrate from water.

Dr. Barwise, of the Derbyshire County Council, recommends the following :—

		Parts per 100,000.
Total suspended matter	less than	3·0
"Oxygen absorbed" at 80° F. in 4 hours		1·5
Albuminoid ammonia (Equal to albuminoid nitrogen 0·12)		0·15
Nitrogen as nitrates	at least	0·25

This last approximates to the Mersey and Irwell standard (excepting that the "oxygen absorbed" test is done at 80° F. instead of 60° F.), but with the addition of a small quantity of nitrate as a safeguarding factor.

Mr. Dibdin has always accepted the standards laid down by the Mersey and Irwell Joint Committee, which he considers very fair working standards. (He determines "oxygen absorbed," however, at a temperature of 80° F. instead of 60° F. and uses a strong permanganate solution). But, in addition, he feels very strongly that the maintenance of the dissolved oxygen, on keeping, at a point above 50 per cent. of the total possible, is one of the most important considerations, as it shows the capability of the effluent to support fish life.

Dr. Rideal judges the quality of an effluent to a large extent from the ratio of oxidized to unoxidized nitrogen in it. At the same time he takes into account the ratio of chlorine to total nitrogen, as giving a good approximation to the original amount of animal matter present in the crude sewage.

Dr. Adeney is opposed to any hard-and-fast standard, being of opinion that standards should vary according to local circumstances, as otherwise small and poor communities might be very hardly dealt with. (Report of the Sewage Commission, 1898, Vol. II. Ques. 2421—2426.)

The West Riding Rivers Board has not published any standard, but we understand from Dr. Wilson that it relies mainly upon the "oxygen absorbed" test at 80° F., and at the same time allows for the presence of nitrate in an effluent.

The Thames Conservancy has likewise not published any standard.

---

* *Note.*—It will be seen that, as regards organic nitrogen, these two standards are pretty much the same. In the final effluents examined for the present Commission from the Cambridge, Altrincham, Beddington and Leicester farms, the albuminoid nitrogen constituted *on the average* almost exactly one-half of the total organic nitrogen (the data for this ratio in the case of the other farms are insufficient).

The Ribble Joint Committee has not officially fixed upon any standard, but uses *provisionally* the following figures as a rough working classification :—

Albuminoid ammonia, if under 0·1 part per 100,000	- - -	Effluent good.
,, ,, 0·15 to 0·2	- - - - - - -	Unsatisfactory.
,, ,, over 0·2	- - - - - - - -	Bad.

Without quoting further opinions, it is thus evident that the views upon standards held by acknowledged authorities on the subject of sewage purification differ considerably from one another.

We do not propose at present to touch upon the question whether or not the chemical standard of purity for an effluent might be allowed to vary within certain limits, according to the volume of the stream into which the effluent flows, but merely to consider upon what principles a standard might reasonably be based, supposing the Commission were ultimately inclined to recommend one.

A standard may be either (1) one of non-putrescibility of an effluent, without any regard to the rate at which that effluent takes up oxygen ; or it may be (2) one non-putrescibility, having regard also to the rate at which oxygen is taken up. It is of course obvious that the second must be the higher standard of the two. In both cases it is assumed that suspended solids are either absent, or at all events are not present in larger quantity than allowed for by the Rivers Pollution Commission.

(1) An effluent may show itself to be non-putrescent under the incubator test, and may be either a good or an indifferent effluent (though the probabilities are in favour of its being good), that is to say, it may be a sample which is already so fully oxidized as not readily to take up oxygen from the water of a stream ; or, on the other hand, it may be only partially oxidized, and therefore prone to take up oxygen from surrounding water, but at the same time be kept from being offensively putrescent by the presence of excess of nitrate* (*cf.* Section upon "Artificial Storm Waters" in this Report). While the incubator or non-putrescibility test is therefore a most valuable one when taken in conjunction with others, it cannot be recommended alone as a basis for a standard. It is not impossible, also, that an effluent only partially purified, but still containing sufficient nitrate to enable it to withstand the incubator test, might tend to deposit colloidal matter which—separated from the nitrate in solution—might be putrescible. Another and not unimportant point to bear in mind is that the incubator test requires several days for completion ; and, moreover, the time limit and the temperature used for this test are quite arbitrary.

(2) Suppose we take the hypothetical case of two sewages *of the same nature*, containing in equal volumes amounts of organic matter expressed by the figures 10 and 5 respectively, then 50 volumes of the first (A) will contain as much organic matter as 100 volumes of the second (B). Hence, if they are both to be purified down to the same *absolute* standard, it is clear that—volume for volume—twice as much purification will require to be done upon A as upon B. Again, the two effluents, $(A)_1$ and $(B)_1$, although they give identical percentage figures for, say, albuminoid nitrogen, are not really equally pure, the effluent from the stronger sewage (A) being as a matter of fact better than the effluent from the weaker one (B) ; for we think it is a point of universal experience that the more the organic matter of an effluent is reduced, the less rapidly fermentable does that residual organic matter become, or, to put this last statement numerically, if two effluents from the same sewage yield albuminoid nitrogen in the proportions of ·2 and ·1 parts per 100,000, the first effluent will be *more than twice* as fermentable as the second, *i.e.*, it will have *more than twice* the tendency to take up oxygen.† Any more or less "absolute" standard like

* *Note.*—There appears to exist doubt in some minds as to whether an effluent, when left to itself, exhausts its dissolved oxygen before beginning to use up its nitrate, or whether both are utilized simultaneously. But we think that the various results bearing upon this point which we have obtained (and which are to be found in the various Chemical Tables of Analyses) are in accordance with the earlier observations of Adency ("Recent Advances in the Bacterio-Chemical Study of Sewage and other Polluted Waters" ; *Engineering*, 1896), which were based on the work of Munro (*Journ. Chem. Soc.*, Vol. 49, p. 651) and of Gayon and Dupetit (*Station Agronomique de Bordeaux*, 1886), and strengthen the conclusion that, in accordance with chemical theory, the oxygen is consumed before the nitrate is touched, provided that the liquid is free from suspended organic matter. Should the latter be present, the upper layers of liquid might still conceivably contain some free oxygen, while the nitrate in solution in the lower layers was being attacked by adjacent organic matter in suspension.

† *Note.*—The experiments upon "Artificial Storm Waters" recorded in this Summary furnish an extreme case of this. They show that dilution of a sewage with tap water down to the Mersey and Irwell effluent standard gives a mixture which putresces upon incubation. Even when the dilution is carried twice as far, *i.e.*, down to half the Mersey and Irwell standard, the mixture will still in all probability be putrescible under those conditions.

the *provisional* one of the Mersey and Irwell Board, therefore, must necessarily press more hardly upon places which have to deal with strong sewages than upon those which treat weak ones.

It might be argued, in reply to the last sentence, that the area of irrigable land on a sewage farm should be proportionate not merely to the volume but also to the organic strength of the sewage which it has to treat (a subject which has been discussed in the General Report; *cf.* Section I; Sub-section 11); but this only partially meets the point, and, in its turn, it raises the question—whether is it easier to purify 50 volumes of a stronger sewage (A) or 100 volumes of a weaker sewage (B) on a given area, the *aggregate* organic matter in both sewages being equal? But with respect to this last query we have no comparative data for an answer.

To return to the hypothetical sewages (A) and (B), containing respectively 10 and 5 parts of organic matter:—If these are purified to the same *proportionate* extent, then the effluents $(A)_1$ and $(B)_1$ will contain, say, ·2 and ·1 parts of albuminoid nitrogen per 100,000, *i.e.*, they will be altogether different if judged by an "absolute" standard, but, as regards the rate at which they will take up dissolved oxygen, they will probably approximate to one another.

It seems, therefore, reasonable to suggest that, if any chemical standard of purity is to be ultimately proposed by the Commission, it should be one depending, at all events partially, upon the rate at which oxygen is taken up, all the more since the diminution of the dissolved oxygen in brook and river waters by effluents is one of the main things which we have actually to guard against. This basis is a scientific one and, further, it is one which follows on the lines of some of the most valuable work that has been done upon sewage, *e.g.*, that of the late Sir E. Frankland,* of Dr. Dupré,* and of Dr. W. E. Adeney,* and others. The principle, too, has for a good while past been practically recognised by men like Messrs. Scudder, Dibdin and Fowler, who carry out "aeration" tests upon this line. For a recent paper on the subject, see also Dr. Rideal, *The Analyst*, Vol. 26. p. 197.

The main objection to a standard depending, in part at least, on the rate of absorption of dissolved oxygen, is that we cannot imitate in the laboratory the ever-changing conditions of a natural stream, and that therefore any dissolved oxygen absorption test that might be recommended for adoption must be an arbitrary one. The whole subject, however, is one with regard to which it would be advisable to collect the views of those workers who have given special attention to the point. There are no doubt already a considerable number of existing records showing the rate of absorption of dissolved oxygen, under definite conditions, by effluents of known chemical composition (in the Mersey and Irwell laboratory, for example, Mr. Scudder has had the "dilution" method of this aeration test in use for a long time); and further records of the kind are being made now for the Commission.

One of the chief difficulties in connection with this is, should the rate of absorption of dissolved oxygen be tested at an uniform temperature all the year round, say, at about 18° C. or 65° F. (which would practically cover the summer temperature of effluents; *cf.* General Report, Section IV.), or should it be determined at the atmospheric temperature of the day? There is a good deal to be argued in favour of either alternative, *e. g.*:—

---

* NOTE.—In the *First Report of the Rivers Pollution Commission, Vol. I., p.* 20, the following passage occurs:—

"The oxidation of the organic matter in water is effected chiefly, if not exclusively, by the atmospheric "oxygen dissolved in the water; such dissolved oxygen being well known to be, chemically, much more "active than the gaseous oxygen of the air. If, therefore, water contaminated with organic matter be perfectly "excluded from the air in a carefully-stoppered bottle, the gradual diminution in the amount of dissolved "oxygen indicates exactly the progress in the oxidation of the organic matter."

In the *Supplement to the Report of the Local Government Board for* 1884–5 there is a paper by Dr. Dupré on "*Changes in Aeration of Water, as indicating the nature of the impurities present in it,*" in which he shows, among other things, that the amount of dissolved oxygen taken up by natural waters, in which bacteria are active, is very much greater than the amount of oxygen which the same waters take up from a solution of permanganate. In other words, one cannot necessarily infer, from the rate of absorption of oxygen from permanganate by an effluent, what the rate of absorption of dissolved oxygen from brook water by the same effluent would be.

Lastly, in the *Transactions of the Royal Dublin Society V.* (*Series II.*), 1895, Dr. Adeney writes:—

"I therefore propose, in this communication, to deal with such experiments as bear directly on the "question with which I started this investigation, viz., *whether the amount of the dissolved oxygen consumed* "*during the complete fermentation of a polluted water might not be regarded, for the purpose of water analysis, as* "*a quantitative index to the amount of fermentable substances originally present in it, provided that during the* "*process care is taken to have the oxygen in excess in the water.*"

(1.) *Test made at uniform temperature.*

(*a*) The standard would in this case remain nearly, though not quite actually, the same throughout the year, taking no account of the temperature at which an effluent was purified (*e.g.*, over land), of its state of dilution or concentration as varying with that temperature, or of the temperature of the stream into which it was discharged; in other words, to put the matter broadly, the comparatively dilute effluent obtained from an irrigation farm in cold frosty weather would be judged by the same standard as the comparatively concentrated effluent got from the same farm in warm weather.

(*b*) On the other hand, the test would not be quite so easy to carry out and, unless there was a laboratory at the sewage farm or works, it could not be applied to an effluent until the latter had reached the laboratory where it was to be tested, which as a rule would be on the succeeding morning. Since the bacteria which are active with regard to the absorption of dissolved oxygen are probably most active within the first 24 hours after the effluent is discharged, this delay might be considered a drawback.

(2) *Test made at the atmospheric or laboratory temperature of the day.*

(*a*) In this case the stringency of the standard would vary with the season of the year, being, of course, greater in warm weather; some people might consider this a recommendation, seeing that nuisance from a bad smell arises much more easily in summer than in winter.

(*b*) But the test would be simpler of execution than in the case of (*a*), and it could, moreover, be put in force the moment a sample was drawn. Thus, a small sample might be aerated by thorough shaking in a large, nearly empty bottle, and the residual oxygen determined 24 hours later, either at the farm or sewage works, or at the laboratory to which the sample was despatched. Or, if more convenient, the dissolved oxygen might be added as Mr. Scudder does it, *i.e.*, in the form of tap water, though this would rather lengthen the time required for the test.

Without making any definite or final statement on the subject at present, we think it would probably be found that any effluent which did not within the 24 hours after drawing take up more than about 3 to 4 c.c. of oxygen per litre (when kept in a full bottle at, say, 18° C. or 65° F.), would be found to be chemically satisfactory. The test might have to be taken in conjunction with the permanganate "oxygen absorbed" test, to provide against the (unlikely) contingency of an effluent being a sterilized one; and, in the present state of our knowledge, it might also be advisable to safeguard it further as regards a maximum of nitrogenous organic matter to be allowed in any effluent at any time (measured, say, by the albuminoid nitrogen), though this additional precaution might in the end be found unnecessary.

We think there can be no doubt that, if it could be satisfactorily and easily worked out in practice, a standard based upon the above principles would deal equably between effluents from strong and weak sewages, not favouring the one at the expense of the other.

The above views with regard to standards were brought before the Commission in 1902, but it may perhaps be desirable to place them on record here.

ROYAL COMMISSION ON SEWAGE DISPOSAL.

SUPPLEMENTARY VOLUMES PRESENTED WITH THE

FOURTH REPORT

OF

THE COMMISSIONERS

APPOINTED IN 1898

TO INQUIRE AND REPORT WHAT METHODS OF

TREATING AND DISPOSING OF SEWAGE

(INCLUDING ANY LIQUID FROM ANY FACTORY OR MANUFACTURING PROCESS)

MAY PROPERLY BE ADOPTED.

VOLUME IV.

REPORTS TO THE COMMISSION BY DR. MCGOWAN, DR. HOUSTON, AND MR. KERSHAW ON LAND-TREATMENT OF SEWAGE.

PART III.—BACTERIOLOGICAL REPORT BY DR. A. C. HOUSTON.

Presented to both Houses of Parliament by Command of His Majesty.

LONDON:
PRINTED FOR HIS MAJESTY'S STATIONERY OFFICE,
BY WYMAN AND SONS, LIMITED, FETTER LANE, E.C.

And to be purchased, either directly or through any Bookseller, from
EYRE AND SPOTTISWOODE, EAST HARDING STREET, FLEET STREET, E.C.; and
32, ABINGDON STREET, WESTMINSTER, S.W.; or
OLIVER AND BOYD, EDINBURGH; or
E. PONSONBY, 116, GRAFTON STREET, DUBLIN.

1904.

[Cd. 1886—II.]

Presented by

Purchased

October 1908

REPORTS

TO THE

ROYAL COMMISSION ON SEWAGE DISPOSAL

ON

LAND TREATMENT OF SEWAGE.

PART III.

BACTERIOLOGICAL REPORT

BY

DR. A. C. HOUSTON.

NOTE.—These Reports to the Commission on Land Treatment of Sewage are published in four parts, viz. :—

Part I.—General Report by Dr. G. McGowan, Dr. A. C. Houston, and Mr. G. B. Kershaw.

Part II.—Chemical Report by Dr. G. McGowan.

Part III.—Bacteriological Report by Dr. A. C. Houston.

Part IV.—Engineering and Practical Report by Mr. G. B. Kershaw.

6225 (iii.) Wt. 26170. 1500—9/04. Wy. & S. A

EXTRACT FROM THE FOURTH REPORT OF THE ROYAL COMMISSION ON SEWAGE DISPOSAL(1904. Cd. 1883).

28th December 1903.

"We have considered it desirable to publish, at this stage, the results and information which have been obtained by our own officers in regard to land treatment of sewage and methods of analysis, but we shall defer reporting on these matters until our investigations, which are now in progress, in regard to other methods of sewage treatment are completed." (Paragraph 117, page xliii.)

CONTENTS.

Introduction.

Section I.—Aldershot Camp Sewage Farm.

„ II.—Altrincham Sewage Farm.

„ III.—Cambridge Sewage Farm.

„ IV.—Croydon (Beddington) Sewage Farm.

„ V.—Leicester Sewage Farm.

„ VI.—South Norwood Sewage Farm.

„ VII.—Nottingham Sewage Farm.

„ VIII.—Rugby (High Level) Sewage Farm.

„ IX.—Sandhurst, Lindfield, Luton, Worsley, Hemsworth, and Derby County Asylum Sewage Farms.

CONCLUSIONS.

Appendix I.—Showing as regards the (1) B. coli and (2) indol tests the results of the bacteriological examination of numerous samples of sewage and effluents.

Appendix II.—Showing as regards the (1) "Gas"; (2) B. enteritidis sporogenes, and (3) Neutral-red broth tests, the result of the bacteriological examination of numerous samples of sewage and effluents.

Appendix III.—Showing as regards the (1) "Gas"; and (2) B. enteritidis sporogenes tests, the results of the bacteriological examination of numerous samples of sewage and effluents.

Appendix IV.—Showing as regards the (1) Neutral-red broth; (2) litmus milk; (3) B. enteritidis sporogenes, and (4) "gas" tests, the results of the bacteriological examination of numerous samples of sewage and effluents.

Appendix V.—Showing the results of the bacteriological examination of average samples of crude sewage.

Appendix VI.—Showing as regards the neutral-red broth test (a) "ordinary" and (b) "spore" curves; and the indol test (a) "ordinary" and (b) "spore" curves, the results of the bacteriological examination of samples of sewage and effluents.

Appendix VII.—Showing as regards Klein's B. enteritidis sporogenes test and the virulence of the typically changed milk cultures, the results of the bacteriological examination of samples of sewage and effluents.

INTRODUCTORY.

General Considerations.

In dealing with the subject matters with which this report is concerned, the following considerations had to be borne in mind :—

The chemical qualities of the effluents from sewage farms have been investigated in the past ; and, although at the commencement of this investigation further information in many directions appeared most desirable, it could not be said that the subject had not already received a large measure of attention.

The contrary, however, was the case as regards the biological qualities of the effluents from sewage farms. In this country, at all events, the matter had received practically no consideration, and the biological qualities of the effluents from sewage farms were unknown.

In the past, it has been the custom to insist, as the result of a broad basis of observed facts, aided by the result of chemical research, on the treatment of sewage on land as the natural and the best way, from the administrative point of view, of disposing of excremental matters. At the period in question, bacteriology had not been brought to bear in any practical manner on the question of sewage disposal.

Within recent times, circumstances have greatly changed. Population has increased, and has tended to become aggregated in districts where land is difficult to acquire and, moreover, is unsuitable in character for sewage disposal. Population has increased too in narrow valleys, where it may be practically impossible to resort to the treatment of sewage on land. The consumption of water per head of this population has likewise increased, and the use of water-closets has become almost universal. Trade has grown largely, and with its growth trade refuse has multiplied, with consequent serious pollution of our watercourses. Advancing education of the masses, with increased importation of foreign foodstuffs and other correlated circumstances, has tended to depopulate country districts. The difficulty of obtaining water supplies for large communities from non-polluted areas is greater than ever before. All these conditions have contributed seriously to alter the whole problem of sewage disposal. Meanwhile bacteriology has come to be considered an indispensable adjunct to chemistry in the re-investigation of the entire subject.

The expectation that by associating the land treatment with chemical treatment the increasing volume of sewage to be dealt with in each town or district could be efficiently purified has been, relatively speaking, disappointed. Nevertheless, chemical treatment, antecedent to land and artificial processes of treatment, has in particular cases been found to be useful.

The modern bacterial treatment of sewage is still in the experimental stage, but, judged by chemical and practical standards, it has so far proved a success in particular, if not in general, cases.

But, it will be asked, *apart from chemical and practical considerations*, what is known of the biological qualities of the effluents from bacterial processes of sewage treatment and of the effluents from sewage farms ?

As regards the effluents from bacterial processes of sewage treatment, the Commission have already received much information, and the subject is still under investigation. The general outcome of these observations has been to afford presumptive evidence of the strongest kind that, until positive evidence to the contrary is forthcoming, it would be wise to regard the effluents from bacteria bed processes of sewage treatment as hardly safer in their possible relation to disease than crude sewage.

As regards the effluents from sewage farms, it remains to be shown what the results of the present investigation have been, and what inferences can be safely drawn therefrom.

The sewage farms investigated; the nature in each instance of the methods of treatment,

	Aldershot Camp Sewage Farm.	Altrincham Sewage Farm.	Cambridge Sewage Farm.
1. Situation of farm	Ashvale.	Near Carrington Moss.	Milton Road, about three miles from Cambridge.
2. Total acreage of farm	138·5 acres.	75 5 acres.	102·5 acres.
3. Total irrigable area	120·5 acres.	35 acres.	74 acres.
4. Average area irrigated at one time	40 acres.	17·5 acres.	18·5 acres.
5. Population draining to farm	20,000	18,000	50,000
6 Population per acre irrigated	166	514	675
7. Gallons of sewage per head per day	50 gallons.	44·4 gallons.	45
8. Dry weather flow of sewage per 24 hours.	1 million gallons.	800,000 gallons.	2¼ million gallons.
9. Gallons of sewage (exclusive of storm water) treated per acre per 24 hours.	25,000 gallons.	46,000 gallons.	121,600 gallons.
10. Gallons of sewage treated per acre per 24 hours, on the assumption that each acre of the irrigable area is under sewage all the time.	8,300 gallons.	23,000 gallons.	30,400 gallons.
11. Characters of the sewage	Domestic.	Domestic.	Mainly domestic (some brewery refuse).
12. Method of treatment	Screening, settling tanks, and land filtration.	Settling tank and land filtration.	Screening, settling tank, and land filtration.
13. General characters of the soil and sub-soil.	Sand.	Peaty (to some extent) soil, lying upon sand and gravel.	Sandy loam overlying gravel and sand.
14. Separate or combined sewerage system.	Separate.	Combined.	Partially separate.
15. The final effluent is discharged into	Blackwater river.	Sinderland Brook.	River Cam.
16. Number of years farm in operation before 1900.	36 years.	30 years.	5 years.

Samples have also been obtained from Luton, Hemsworth, Derby County

INVESTIGATED.

soil on the farm, the character of the sewage, and method or with other particulars :—

Beddington (Croydon) Sewage Farm.	Leicester Sewage Farm.	South Norwood Sewage Farm.	Nottingham Sewage Farm.	Rugby Sewage Farm.
Beddington.	Two miles from Leicester.	Near South Norwood.	Stoke Bardolph, five miles from Nottingham.	New Bilton, one mile from Rugby.
673·5 acres.	1699 acres.	191 acres.	907 acres (1900).	40 acres.
420 acres.	1350 acres.	152 acres.	651 acres (1900).	35 acres.
70 acres.	337 acres.	50 acres.	300 acres.	7 acres.
100,000	197,000	21,000	258,584	6,000
238	146	138	397	171
40 gallons.	36·8	28·5	27	50
4 million gallons.	7¼ million gallons.	600,000 gallons.	7 million gallons.	300,000 gallons.
57,100 gallons.	21,500 gallons.	12,000 gallons.	23,300 gallons.	42,800 gallons.
9,500 gallons.	5,370 gallons.	4,000 gallons.	10,750 gallons.	8,500 gallons.
Domestic.	¾ domestic, ¼ trade refuse.	Purely domestic.	⅘ domestic ⅕ trade refuse.	Mainly domestic.
Screening Surface irrigation and a little filtration.	Screening, settling tanks, surface irrigation and filtration combined.	Screening, settling tanks and surface irrigation.	Screening, (partial), and land filtration.	Screening, chemical precipitation, settling tanks, and surface irrigation and filtration combined.
Gravelly loam, overlying gravel and sand.	Stiff clayey soil overlying dense clay.	A clay soil resting on London clay.	Light sandy loam, and gravel overlying gravel and sand.	Heavy loam overlying stiff clay.
Partially separate.	Partially separate.	Partially separate.	Combined.	Partially separate.
River Wandle.	Anstey Brook (flowing into River Soar).	Chaffinch Beck.	River Trent.	River Avon.
39 years.	9 years.	36 years.	19½ years.	33 years.

Asylum (Mickleover), Lindfield and Sandhurst sewage farms.

Methods of Bacteriological Investigation.

The methods of bacteriological investigation carried out in this inquiry have been those laid down by me as essential early in 1898, namely :—

Routine tests.

(1) *Quantitative estimation* of B. coli.*
(2) Number of spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anaerobic milk cultures).

Together with the periodical enumeration of the:—

(a) Total number of bacteria (gelatine at 20° C.).
(b) ,, ,, ,, (agar at 37° C.).

Occasional tests.

(a) Streptococcus test ; (b) inoculation of animals ; (c) enumeration of spores of aerobic bacteria, etc.

Simple tests.

In addition to the above, much work, at the request of the Commission, has been carried out on the subject of simple tests, *e.g.* (a) indol; (b) "gas" ; (c) neutral-red broth ; and (d) litmus milk tests.

I have already reported to the Commission on the subject of tests, provisional standards and the relative values of chemical and bacteriological tests, in reference to effluents according as they are to discharge into drinking water streams or into non-drinking water streams.†

Fundamental Distinction Between the Discharge of Effluents into Drinking Water and Non-Drinking Water Streams.

In carrying out this investigation, the fundamental distinction between the discharge of effluents into drinking water and non-drinking water streams, respectively, had to be borne in mind. In this connection, I may quote from my previous report as follows :—†

"It seems quite clear that a chemical examination of effluents will be required in the case of both potable and non-potable rivers. In both cases it is necessary to prevent the discharge into the river of an undue amount of oxidisable and putrescible matter. Even if an effluent were sterilised, a chemical examination would still be required to show that it contained no organic substance susceptible to the action of putrefactive bacteria present in the water of the river. Cases have occurred where an effluent rich in putrescible matter has been actually sterilised, but which nevertheless produced a filthy nuisance in the river some distance below the point of discharge.

The time is past usefully to discuss whether it is better to have a sterile effluent rich in organic matter, or a non-sterile effluent free, or nearly so, from putrescible matter. All effluents, whether sterile or non-sterile, must be relatively free from all substances susceptible to the action of putrefactive bacteria. Further, at all events in the case of drinking water streams, it is necessary for the chemist to say whether the effluent is free from chemical poisons in dangerous amount."

Drinking Water Streams.

While admitting the absolute necessity of a chemical examination of effluents in the case alike of drinking water and non-drinking water streams, it was pointed out that in the former case (drinking water streams) the

---

* Preferably by *isolation and study in pure culture*, not by inferring the presence of B. coli from the result of changes produced in a medium and supposed to be characteristic of B. coli.

† *See* Second Report of the Royal Commission on Sewage Disposal. [1092 Cd. 1178.]

bacteriological examination was far more important than the chemical. Thus :—

> "Organic matter *per se* in water is seemingly harmless ; it is the bacteria likely to be associated with the organic matter that constitute the element of danger. Only by bacterioscopic analysis, can we hope to detect the kinds of bacteria in an effluent which are of a sort liable to be related to disease. Chemistry is quite powerless in this respect, and, indeed, all chemical "standards of potability" are apparently based on an assumed relationship, which may or may not exist, between the amount of organic matter and the num er and kinds of the associated bacteria. Typhoid fever stools, whether sterilised and innocuous, or unsterilised and highly dangerous, would yield to chemical testing practically the same results as regards the nature and amount of organic matter present."

It was pointed out that, although on scientific grounds desirability of the complete removal or destruction of all bacteria (sporing and non-sporing) of intestinal outcome is strongly indicated, it was doubtful whether this counsel of perfection would be wholly defensible in practice. Further, as an alternative to the complete sterilisation (destruction of all microbes, sporing and non-sporing) of effluents, it was suggested that partial sterilisation to the extent of killing B. coli might be a reasonably safe standard to adopt. It is not proposed, in this report, to deal with the practical aspects of this recommendation, but only with the nature and amount of evidence in favour of its adoption.

One point, however, may be touched on, namely, that it will doubtless be contended that sterilisation should be carried out at the waterworks, not at the effluent outfalls. Apart from questions of equity, a single practical objection to such contention may be advanced. The volume of water used for waterworks purposes may be very large in proportion to the volume of effluent admitted into the drinking-water stream; and so in such a case there would be an economic advantage in sterilising the effluent instead of the water. The question of sterilisation will be dealt with in a separate report.

Tests Advocated in the Case of the Discharge of Sewage Effluents into Drinking Water Streams.

It will be asked, how is it practicable to *compare different effluents, as regards their degree of potential harmfulness*? This aspect of the question has been fully dealt with in previous reports, and all that seems necessary here to be recapitulated is the broad basis of reasoning which has guided the bacteriological investigations throughout the inquiry.

In the first place, it is indisputable that, at present, there are, beyond evidence of complete or partial sterilisation, no infallible biological data enabling the bacteriologist to say of an effluent that it is wholly, or relatively harmless ; and it is well known that failure to isolate definitely pathogenic microbes from a suspected liquid affords no absolute proof of the complete absence from the liquid of such microbes.

Secondly, on the basis of observed facts and reviewing the history of epidemics traced to polluted water, it is assumed that crude sewage is always a potentially dangerous liquid.

Thirdly, the relative abundance of the microbes (*e.g.* B. coli, B. enteritidis sporogenes, streptococci, etc.)* characteristic of sewage in the sense of being almost peculiar to or specially abundant in it, has been determined. These

* Some streptococci and some strains of B. coli are pathogenic to animals and are also related to morbid processes occurring in the human subject. Further, in the opinion of Dr. Klein, the presumptive evidence in favour of B. enteritidis sporogenes having been causally connected with certain epidemics of diarrhœa is of a strong kind. Nevertheless, I am not here basing the value of these tests on the assumption that these micro-organisms are directly injurious, but am advocating the safer view, namely, that their quantitative estimation is an indirect means of measuring the status of an effluent in its possible relation to disease.

bacteria have been termed "microbes of indication," because it is believed that their presence (and their proportionate number) in a liquid is an indication of the possibility (and broadly of the degree of probability) of the presence as well of other micro-organisms causally associated with the occurrence of epidemic disease.

Fourthly, the determination of the relative abundance of these bacteria ("microbes of indication") in an effluent has been considered a trustworthy indication of the degree of biological purification effected by the particular process of sewage treatment under investigation; and a means, therefore, of measuring the degree of biological modification that the sewage, in respect of its original objectionable qualities, has undergone as a result of the treatment In other words, the status of an effluent, in respect of possible danger to health, is judged by the greater or less abundance in it of these "microbes of indication." *

It will be said, if a sterilisation standard is adopted, these tests would be unnecessary. This is true. But the Commission has still to decide on this important question, and their decision thereon must inevitably be influenced by the *degree of probable danger to health* shewn as the results of these *quantitative biological* investigations.

Moreover, as an alternative to sterilisation, standards of "relative safety" might be chosen. For example, standards one hundred times more severe than those suggested in connection with non-drinking water streams.

The above contentions and inferences are based on a common-sense interpretation of the results yielded by recent bacteriological research, controlled or at least greatly influenced by the teachings in the past of distinguished epidemiologists. In the present state of our knowledge, these inferences are believed to be sound; but it is possible that future discovery may show that, in some directions, they are unduly moderate in character, and, in other directions, open possibly to the charge of over-estimation of the danger likely to arise from the discharge of sewage effluents into drinking water streams.

Non-drinking Water Streams.

In considering as a means of spreading disease, the possibilities of the discharge of a bacterially-impure effluent into non-drinking water streams, it is desirable to quote from my previous report as follows† :—

"All streams which are not brackish or obviously offensive to taste or smell, or which do not present strongly to the eye the appearance of pollution, are liable to be used as sources of drinking water occasionally or even habitually by some individuals.

"Bathing is commonly indulged in in non-drinking water streams. Whatever may be said of its comparative harmlessness, numerous cases of sickness and diarrhœa have been referred to this practice. And it would of course be quite possible for typhoid fever and cholera to be spread in this way.

"Further, there is always the possibility of the water of non-drinking streams being brought into relation with articles of food or drink. For example, the reprehensible practice of rinsing milk cans in water of this class may specially be cited. Again, watercress is frequently grown in sewage-polluted water.

---

* It must, of course, be remembered that the dangerous qualities of sewage effluent depend rather on the presence of living microbes than of chemical poisons, and that therefore the danger is not necessarily proportional to the dose. The presence of definite specific germs of disease may render a seemingly trivial degree of pollution highly dangerous; the absence of pathogenic organisms may mean that a gross contamination is actually, or relatively, harmless. But it has already been pointed out that, in the case of non-sterile effluents, no biological test is available enabling the bacteriologist to prove the complete absence of all disease germs. It is necessary, therefore, to gauge the status of an effluent from the point of view of possible danger to health, by estimating the *relative abundance*, whenever present, of those microbes of excremental origin which are associated with the specific germs of disease.

† *See* Second Report of Royal Commission on Sewage Disposal. [1902. Cd. 1178.]

"It has been asserted that there is danger in eating fish caught in sewage-polluted streams. But any danger that might be supposed to exist should be removed by cleansing and cooking the fish. In the case of oysters and other shell-fish (tidal waters), when eaten in the raw condition, the risk, however, may be very real.

"There would also seem to be some danger of wells in the vicinity of polluted streams becoming contaminated. Soil is a very efficient filter under ordinary conditions, but sometimes fissures exist which may allow sewage matters to travel underground for a considerable distance in a practically unaltered condition. Moreover, soil may in course of time become so polluted as to be saturated with germs, and in such cases the microbes tend more and more to spread beyond their original limits. Lastly, floods may carry sewage-polluted water over the surface of adjoining land and so contaminate wells.

"Some authorities consider that cattle suffer from drinking the water of sewage-polluted streams. But of this there is no definite proof.*

"Then there is the question of flood water depositing suspended matter and innumerable bacteria on the river banks. These matters in the dry condition may be carried by the wind for a considerable distance.

"The possibility of danger to health from the inhalation of noxious gases emanating from polluted streams is a separate question, and will not be considered here.

"These factors, considered separately, may be of no great importance; taken together they cannot, as it seems to me, be entirely ignored."

"A broad view of the case would seem to be that the danger is not abundant or far-reaching; that it tends to affect individuals rather than large communities. And although a single case of typhoid fever may, if circumstances favour it, create a widespread epidemic, too much stress should not be laid on concrete instances, but reliance placed rather on general considerations."

"After careful consideration, I should be inclined to say that in the case of non-drinking-water streams, *except where oysters and other shell-fish which are eaten raw are concerned*, the bacteriological character of an effluent is of secondary importance.*

"But even from this secondary point of view, the bacteriological examination may be of considerable utility for ascertaining the actual or potential putrescibility of an effluent."

The position of the bacteriologist, in relation to non-drinking water streams, would really seem to be this :—

"Putrefaction cannot take place (whatever the number and sorts of bacteria present may be) in the absence of putrescible and oxidisable organic matter, and" the bacteriologist has "no direct means of estimating dead organic matter."

"Indirectly, however, the bacteriologist can in most cases obtain a reliable indication of the degree of putrescibility of a liquid by estimating the number and observing the character of the bacteria contained in it."

"In brief, the position of the bacteriologist as regards non-potable streams is very much that of the chemist in relation to drinking-water streams. In both cases, the truth is sought for by necessarily indirect methods, and by assuming a relationship, in the former case, between the number of putrefactive bacteria and the amount of organic matter, and in the latter case between the amount of organic matter and probable presence of microbes of pathogenic sort."

* See, however, my Report on the Presence of Anthrax at Yeovil, in (1) Septic Tank Liquor; (2) Septic Tank Sludge; (3) Primary Coarse Coke Bed; (4) Secondary Fine Coke Bed; (5) General Effluent from Final Catchpit in a Hide Factory; (6) Mud of River Yeo; and (7) Mud of Yeo Brook. (Second Report of Royal Commission on Sewage Disposal. [1902. Cd. 1178]).

Tests advocated in the Case of the Discharge of Sewage Effluents into Non-Drinking Water Streams.

The nature of the tests advocated in the case of the discharge of sewage effluents into drinking water streams, and the interpretation to be placed on the results obtained by the use of each, will not, I think, be disputed. But the question arises, whether or not tests of like nature are applicable to the case of non-drinking water streams? That the results of such tests may be interpreted in a widely different sense has been already shewn; and it only remains to add that, in the present state of our knowledge, like tests may be usefully employed in each case. Nevertheless, there can be no question that future work may show that, in the case of non-drinking water streams, there are to be obtained, for determining the potential putrescibility of effluents, better tests than those now employed in estimating, in respect of danger to health, the status of effluents destined to discharge into drinking water streams.

A knowledge of these *in futuro* tests might greatly enhance the value of a bacteriological examination of sewage effluents.

If such tests are discovered, it would be no difficult task to ascertain, by comparative observations, how far they harmonise with existing tests. Assuming that a parallelism of some kind would exist, the records of results now being obtained from the ordinary tests would not, in the future, necessarily cease to be of value. Such a comparison indeed might show that the tests now in use have a much higher value than is at present appreciated. For this and for the other reasons previously suggested, it would seem not inadvisable to retain a bacteriological standard, even in the case of non-drinking water streams. A contrary view might involve, in the future, a consequent discouragement of bacteriological research in directions not free from useful possibilities.

The danger (if danger there be) of discharging into non-drinking water streams sewage effluents teeming with microbes of intestinal origin may not be capable of easy demonstration. But, in this connection, it is well to remember that progress in Preventive Medicine has not been achieved, as a rule, by waiting for overwhelmingly positive evidence of harmfulness, but in anticipating, on the basis of observed facts, possible danger to health, by observance of the conditions which make for health and by avoidance of those which make for disease. The chemist and bacteriologist have usually followed in the footsteps of the pioneers of sanitary science, and their combined investigations have commonly gone to establish (rarely to controvert) the wisdom of past sanitary teaching. Apart from the question of practicability and of convincing proof of harmfulness, it is not in accordance with the principles of sanitary science to place no control on the broadcast discharge, even into non-drinking water streams, of myriads of intestinal microbes.

At present, however, all that can be said is that the tests now in use have in practice proved by no means unreliable, although they afford necessarily indirect indication only of the potential putrescibility of sewage effluents; the decline, in effluents as compared with sewage, in the number of bacteria of all sorts and the decline also in the number of particular microbes (*e.g.*, B. coli and, but possibly to a less extent, B. enteritidis sporogenes) may be thought of as usually taking place in broad correspondence with the destruction of the putrescible organic matter.*

Standards.

In the case of *drinking water streams*, the standard which I advocate is partial sterilisation, the destruction of B. coli to the extent of securing its absence in 1 c.c. of the effluent being taken as satisfying such standard. Complete sterilisation of sewage effluents would not seem to be a practical measure, otherwise this higher standard would be recommended.

As regards *non-drinking water streams*, the standards which I recommend

* These are matters which require time even for their practical solution. It is not to be expected that progress can be other than slow.

are *provisional and for working purposes* only. For the chief tests employe they are as follows :—

Total number of bacteria.	Gelatine at 20° C.	Less than 100,000 per c.c.
	Agar at 37° C.	Less than 10,000 per c.c.
B. coli, less than 1,000 per c.c.		
*B. enteritidis sporogenes test and "Gas" test (24 hours at 20° C.)		Negative results with 0·1 c.c.
Indol test (5 days at 37° C.)		Negative result with 0·001 c.c.
Neutral-red broth test (2 days at 37° C).		
Bile-salt broth test (2 days at 37° C).		
Litmus milk (modified) test (2 days at 37° C).		

These are primary standards ; my secondary standards are arrived at by rendering the primary standards ten times more lenient.

It may be asked : Is it not possible to reject artificial processes of sterilisation and apply the above same tests, but with more stringent standards, to the case of drinking water streams ? The answer for obvious reasons is in the negative, from the epidemiological point of view ; but from the practical standpoint, it may be said that *relative* safety would *probably* be secured by making for effluents destined to discharge into drinking water streams, the above standards one hundred times more stringent.†

Summary.

In summary of the foregoing it may be pointed out:—

1. That circumstances have greatly changed since land treatment was regarded as not only the natural, but also the best, method of purifying sewage.

2. That the changed conditions have led, among other things, to not unsuccessful attempts to purify sewage by artificial processes.

3. That it has become necessary, in reference to their purifying values, to compare (bacteriologically as well as chemically) very closely (a) natura (land), and (b) artificial (bacteria bed) processes of sewage treatment.

4. That chemical standards are necessary, both in the case of drinking water and non-drinking water streams.

5 (a). That *in the case of drinking water streams* a bacteriological is of more importance than a chemical standard.

5 (b). That the biological tests recommended in this connection are those which deal with the estimation of the relative abundance of microbes of intestinal origin (microbes of indication), in sewage and sewage effluents.

5 (c). That the status of an effluent, from the point of view of potential danger to health, may be judged by the numerical estimation of these "microbes of indication" (*e.g.* B. coli, B. enteritidis sporogenes, streptococci, etc.)

5 (d). That although the complete sterilisation of sewage effluents is recommended as a counsel of perfection, the standard suggested as a practicable one is partial sterilisation, (absence of B. coli from 1 c. c. of the effluent).

6 (a). That in the case of *non-drinking water streams*, a bacteriological standard is of secondary importance, but it may prove valuable as an adjunct to the chemical standard.

6 (b). That at present tests of the same sort may be usefully employed in the examination of effluents, which are being discharged into non-drinking water

* It will be seen from the results detailed in Appendix VII. that, in connection with the routine use of the B. enteritidis sporogenes test, the habitual inoculation of rodents is neither necessary nor wholly justifiable.

† This tentative statement may be safeguarded further by assuming (1) a ten-fold dilution of the effluent with river water ; (2) a flow between the effluent outfall and the intake for waterworks purposes of at least one mile ; and (3) subsequent filtration of the river water.

streams, as are recommended in the case of drinking-water streams; it should be understood however that the tests are to be regarded as an *indirect* way of measuring the probable degree of purification of the sewage that has been effected. Meanwhile it is to be borne in mind that future work may show that the potential putrescibility of effluents may be best judged by other, though at present unknown, biological tests.

6 (c). That the discovery *in future*, of biological tests accurately defining, in relation to the degree of purification effected by one and another kind of treatment, the status of an effluent would alter the whole complexion of the subject, and might make the bacteriological verdict in the case of an effluent which is to be turned into a non-drinking water stream almost as authoritative as would now be possible, if the safety or otherwise of a drinking water stream were in question.

6 (d). That it seems advisable to place some limit on the discharge of myriads of microbes of intestinal origin into non-drinking water streams, always provided that control in this sense is practicable and that bacteriological can be brought into harmony with chemical standards.

6 (e). That the provisional standards* suggested for comparative and working purposes, to apply to non-drinking water streams, are as follows :—

Total number of bacteria.	Gelatine at 20° C. Less than 100,000 per c.c. Agar at 37°C. Less than 10,000 per c.c.
B. coli, less than 1,000 per c.c.	
B. enteritidis sporogenes test "Gas" test (24 hours at 20°C.).†	Negative results with 0·1 c.c.
Indol test (5 days at 37°C.). Neutral-red broth test (2 days at 37° C.). Bile-salt broth test (2 days at 37° C.). Litmus milk (modified) test (2 days at 37° C.).‡	Negative results with 0·001 c.c.

I have to acknowledge much valuable assistance rendered me by Dr. Gordon during the whole of the investigations, especially as regards the numerical estimation and study of the coli-like microbes present in the various samples of sewage and effluents (*see* Appendix I.). These records, in my opinion, are of great importance. More recently, Miss Hartley has carried out much useful work in connection with routine tests. Miss Power has greatly assisted me while this report has been passing through the press.

---

* There are primary standards; my secondary standards are arrived at by rendering the primary standards ten times more lenient. *It must be definitely understood that these standards are not suggested in an administrative sense; they are merely arbitrary and designed solely for comparative purposes.*

† Observations are now made after 24, 48, and 72 hours' incubation at 20° C.; the standard being varied according to the duration of incubation.

‡ The composition of this medium, as at present in use, is as follows :—Milk 20 per cent; sodium carbonate 0·1 per cent.; lactose 1 per cent.; peptone 2 per cent.; water 76·9 per cent.; tinted with litmus solution.

SECTION I.

ALDERSHOT CAMP SEWAGE FARM.

1. Situation of farm.—Ashvale, close to camps.

2. Total acreage of farm.—138·5 acres.

3. Total irrigable area.—120·5 acres.

4. Average area irrigated at one time.—About 40 acres.

5. Population draining to farm.—20,000.

6. Population per acre irrigated.—166.

7. Gallons of sewage per head per day.—50.

8. Dry-weather flow of sewage per 24 hours.—1,000,000 gallons.

9. Gallons of sewage (exclusive of storm water) treated per acre per 24 hours.—25,000 = $(\frac{1000000}{40})$.

10. Gallons of sewage treated per acre per 24 hours, on the assumption that each acre of the irrigable area is under sewage all the time. (This for purposes of comparison) = $(\frac{1000000}{120 \cdot 5})$ = 8,300 gallons.

11. Characters of the sewage.—Purely domestic.

12. Method of treatment.—Screening, settling tanks and land filtration

13. General characters of the soil and subsoil.—Sand.

14. Separate or combined sewerage system.—Separate.

15. The final effluent is discharged into.—River Blackwater.

16. Number of years farm in operation before 1900.—36 years

A full description of Aldershot Camp Farm will be found in Mr. Kershaw's report (Part IV., Engineering and Practical Report). It seems, therefore, almost unnecessary to discuss the matter here. But a few points of importance may be noted in the briefest manner possible, namely, as follows :—

The soil of the farm consists of sand which, by constant sewaging and the occasional ploughing in of sludge incorporated with farmyard manure, has acquired a surface layer of humus some 4 in. to 12 in. in depth. Up to a certain point, the sandy character of the soil might be expected to lead to a mechanical separation of the sewage microbes. But when sewage is more or less continuously applied to it, the land tends to become saturated, as it were, with microbes, and then each fresh application of sewage washes out a greater or less number of the mechanically-separated bacteria. It should be specially noted that practically all the irrigable land has been extensively "dressed" with chalk. The sewage is purely domestic ; there are no privies, but only water-closets used throughout the camp. The separate system is in use at Aldershot camp, and the separation of the roof and surface water from the sewage proper is actual not merely nominal. The method of treatment consists of screening, settling, and land filtration. The effluents are treated once only. The amount of subsoil water gaining access to the sewers is not great, and on the farm itself but little subsoil water reaches the under drains. The consumption of water is so great as to bring the volume of sewage up to the high average of 50 gallons per head. The sludge, mixed with farmyard manure, is ploughed into the land. The farm has been carefully under-drained. Mr. Kershaw, in his report, deals very fully with the way the land is worked, and any reference here to this part of the subject would be incomplete and, possibly, misleading, and so may with advantage be omitted.

The effluents finally pass into the river Blackwater. The staple crop is rye-grass, together with cabbages and mangold-wurzel. The gross area of the farm is about 138 acres, the irrigable area about 120 acres, dealing with 1,000,000 gallons per 24 hours. Each acre of irrigable area deals daily with the sewage of 166 persons, amounting in bulk to 8,300 gallons, but as only about one-third of the irrigable area is sewaged at one time, this means the sewage (24,900 gallons) of 498 persons is treated per acre per 24 hours.

The following is a summary of the several sections of the report in so far as it relates to Aldershot Sewage Farm :—

1. Tabular statement and summary of the chief bacteriological results.

2. Diagram 1 illustrating the results shown in Table 1, with comments thereon.

3. Results considered in connection with Mr. Kershaw's notes.

4. Results in relation to tests other than the B. enteritidis sporogenes test.

5. Grouping of the effluents based on Mr. Kershaw's notes.

6. Results of the bacteriological examination of additional samples of river water, subsoil water, and "street washings," with accompanying table.

7. General conclusions.

Addendum A.—Results of the examination by means of simple tests of samples obtained from Aldershot Camp Sewage Farm. (Special comparative series of experiments.)

Addendum B.—Comparative records as regards (a) the "gas," and (b) B. enteritidis sporogenes tests of samples obtained from Aldershot as well as other sewage farms.

Addendum C.—General comparison as regards (a) the "gas," (b) B. enteritidis sporogenes, (c) neutral-red broth, and (d) litmus milk tests of samples obtained from Aldershot as well as other sewage farms.

Addendum D.—Additional bacteriological notes.

Addendum E.—Mr. Kershaw's abridged notes to accompany bacteriological report.

1. *Tabular Statement and Summary of the chief bacteriological results.*

The following table (Table 1) shows as regards the total number of bacteria ; B. coli and spores of B. enteritidis sporogenes, the results of the bacteriological examination of thirteen samples of sewage and forty-seven samples of effluent :—

TABLE 1.—Showing as regards the total number of bacteria, B. coli, and spores of B. enteritidis sporogenes, the results, of the bacteriological examination of samples of sewage and effluents obtained from Aldershot Sewage Farm.

Sewages.

Description of the Sample.	Total Number of bacteria per c.c.		Number of B. coli (or closely allied forms) per c.c.	Number of Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in milk culture) per c.c.
	Gelatine at 20° C.	Agar at 37° C.		
1.	2.	3.	4.	5.
48 Raw sewage - - - 11 a.m. 12th March 1900.	57,700,000	6,340,000	At least 100,000 -	+ ·001, – ·0001 c.c. At least 1,000 but less than 10,000.
50 Settled sewage - - - 11 a.m. 14th March 1900.	23,400,000	690,000	- ditto - -	- ditto - ditto.
54 Settled sewage - - - 1 p.m. 21st March 1900.	27,600,000	900,000	- ditto - -	- ditto - ditto.
81 Settled sewage - - - 11.45 a.m. 28th May 1900.	42,700,000	9,560,000	- ditto - -	+ ·01, – ·001 c.c. At least 100 but less than 1,000.
86 Settled sewage - - - 12.45 p.m. 5th June 1900.	26,300,000	2,240,000	- ditto - -	- ditto - ditto.
245 Settled sewage - - - 2 p.m. 1st April 1901.	43,300,000	15,760,000	*See* simple tests -	+ ·001, – ·0001 c.c. At least 1,000 but less than 10,000.
302 Settled sewage - - - 11.5 a.m. 19th June 1901.	22,300,000	2,580,000	At least 100,000 -	- ditto - ditto.
303 Settled sewage - - - 11.30 a.m. 19th June 1901.	36,400,000	1,240,000	- ditto - -	+ ·0001, – ·00001 c.c. At least 10,000 but less than 100,000.
306 Settled sewage - - - 11.40 a.m. 24th June 1901.	21,680,000	3,480,000	- ditto - -	+ ·001, – ·0001 c.c. At least 1,000 but less than 10,000.
314G Crude sewage - - - 11.5 a.m. 8th July 1901.	34,800,000	7,400,000	*See* simple tests -	- ditto - ditto.
319B Crude sewage - - - 10.35 a.m. 16th July 1001.	*See* simple tests	2,490,000	- ditto - -	- ditto - ditto.
323A Crude sewage - - - 11.30 a.m. 22nd July 1901.	- ditto -	5,320,000	- ditto - .	+ ·0001, – ·00001 c.c. At least 10,000 but less than 100,000.
325A Crude sewage - - - 9.45 a.m. 24th July 1901.	- ditto -	*See* simple tests	- ditto - -	+ ·001, – ·0001 c.c. At least 1,000 but less than 10,000.
Average - - -	33,618,000	4,833,333	[Ratio cols. 2 : 3 6·9 : 1]	

Effluents.

				Winter Visit, 1900:
49 Effluent, old land - - 3.15 p.m. 12th March 1900.	20,000	196	10 not 100 -	+ ·1, – ·01 c.c. At least 10 but less than 100.
51 Effluent, old land* - - 3.15 p.m. 14th March 1900.	9,100	280	At least 10 - -	- ditto - ditto.
52 Effluent, old land - - 11.15 a.m. 19th March 1902.	8,600	440	At least 1, not 10 -	+ 1, – ·1 c.c. At least 1 but less than 10.
53 General effluent, old land - 11.30 a.m. 19th March 1900.	110,000	7,300	1,000 not 10,000 -	+ ·1, – ·01 c.c. At least 10 but less than 100.
55 Effluent, old land - - 4 p.m. 21st March 1900.	37,700	430	10 not 100 - -	- ditto - ditto
56 General effluent, old land - 12,15 a.m. 27th March 1900.	410,800	16,000	1,000 not 10,000 -	- ditto - ditto.
82 Effluent, new land A - - 3 p.m. 28th May 1900.	520,000	15,700	At least 1,000 -	+ ·01, – ·001 c.c. At least 100 but less than 1000.
				Spring Visit, 1900:
83 Effluent, new land A - - 3.15 p.m. 29th May 1900.	650,000	47,000	- ditto - -	+ ·1, – ·01 c.c. At least 10 but less than 100.
84 Effluent, new land A - - 3.15 p.m. 30th May 1900.	250,000	53,900	1000 not 10,000 -	+ ·001, – ·0001 c.c. At least 1,000 not 10,000.
87 Effluent, new land A - - 3 p.m. 5th June 1900.	1,750,800	98,000	10,000 not 100,000 -	+ ·01, – ·001 c.c. At least 100 but less than 1,000.
88 Effluent, new land A - - 3.15 p.m. 6th June 1900.	820,000	179,000	- ditto - -	+ ·1, – ·01 c.c. At least 10 but less than 100.
89 General effluent old land - 2.30 p.m. 6th June 1900.	186,000	860	At least 100 - -	- ditto - ditto.
				Spring Visit, 1901:
246 General effluent, old land - 2.15 p.m. 1st April 1901.	86,000	2,000	*See* simple tests in Appendices at end of report.	+ ·1, – ·01 c.c. At least 10 but less than 100.
247 Effluent, old land - - 3 p.m. 1st April 1901.	7,000	530	- ditto - -	+ 1, – ·1 c.c. At least 1 but less than 10.

* This sample was examined for the presence of streptococci, but no streptococci could be found in agar plate cultures (at 37° C.) inoculated with ·1 and ·01 c.c. of the sample.

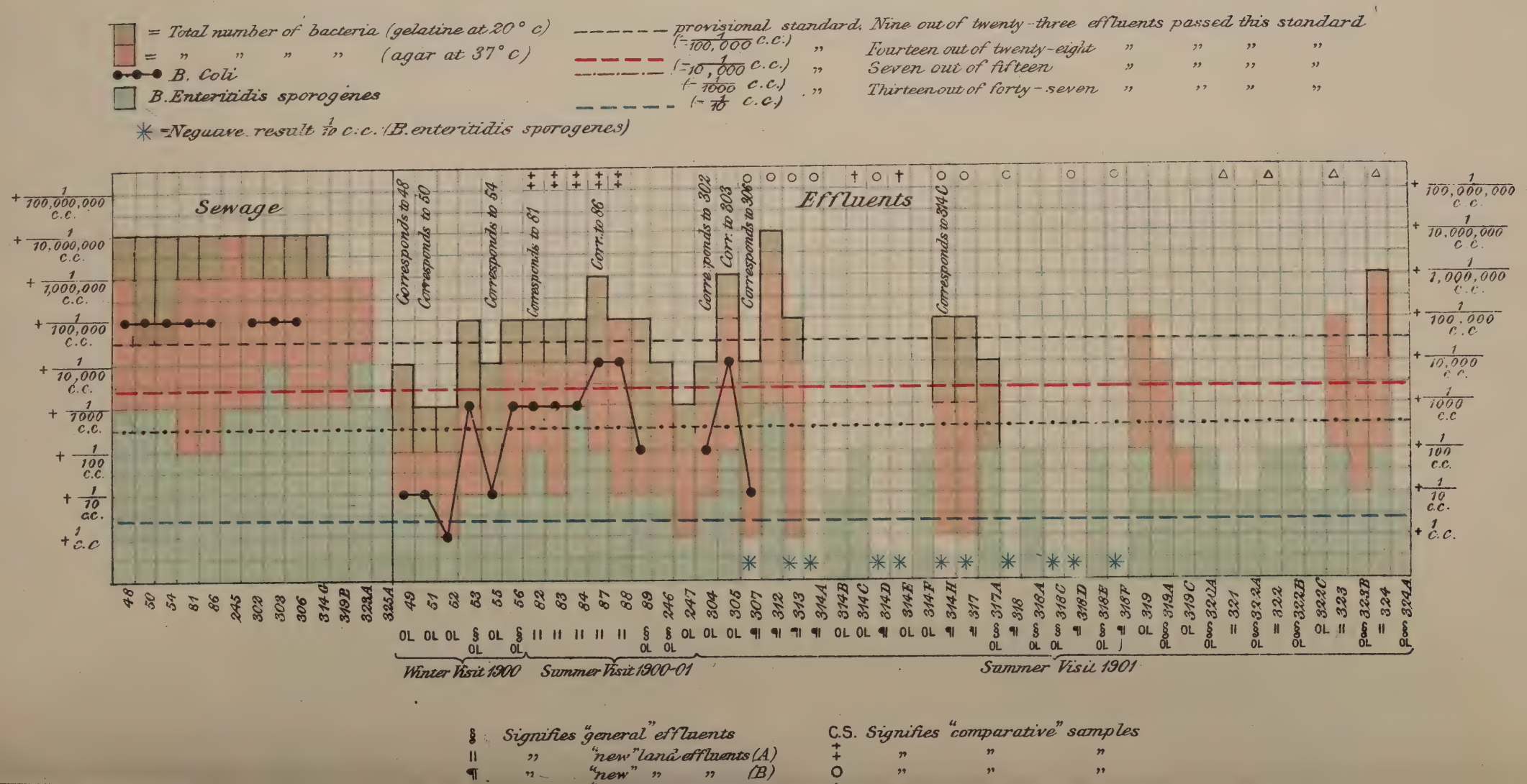
Effluents—*continued.*

Description of the Sample.	Total Number of bacteria per c.c.		Number of B. coli (or closely allied forms) per c.c.	Number of Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in milk culture) per c.c.
	Gelatine at 20° C.	Agar at 37° C.		
1.	2.	3.	4.	5.
				Summer Visit 1901:
304 Effluent, old land - - 12.30 p.m. 19th June 1901.	66,000	3,300	At least 100 - -	+ ·1, – ·01 c.c. At least 10 but less than 100.
305 Effluent, old land - - 12.45 p.m. 19th June 1901.	1,220,000	124,000	At least 10,000 -	+ ·01, – ·001 c.c. At least 100 but less than 1,000.
307 Effluent, new land B - - 12.45 p.m. 24th June 1901.	11,100	140	Less than 100 -	– ·1 c.c. None in $\frac{1}{10}$ c.c.
312 Effluent, new land B - 1 p.m. 2nd July 1901.	10,400,000	1,320,000	*See* simple tests in Appendices at end of report.	+ ·001, – ·0001 c.c At least 1,000 but less than 10,000.
313 Effluent, new land B - 11 a.m. 3rd July 1901.	760,300	58,000	- ditto - -	– ·1 c.c. None in $\frac{1}{10}$ c.c.
314A Effluent, new land B - 11.10 a.m. 4th July 1901.	*See* simple tests in Appendices at end of report.	*See* simple tests in Appendices at end of report.	- ditto - -	– ·1 c.c. None in $\frac{1}{10}$ c.c.
314B Effluent, old land - - 11.30 a.m. 4th July 1901.	- ditto -	- ditto	- ditto - -	+ ·1 c.c. – ·01 c.c. At least 10 but less than 100.
314C Effluent, old land - - 11.45 a.m. 4 July 1901.	- ditto -	- ditto -	- ditto - -	+ ·01, – ·001 c.c. At least 100 but less than 1,000.
314D Effluent, new land B - 10.30 a.m. 5th July 1901.	- ditto -	- ditto -	- ditto - -	– ·1 c.c. None in $\frac{1}{10}$ c.c.
314E Effluent, old land - - 11 a.m. 5th July 1901.	- ditto -	- ditto -	- ditto -	- ditto - ditto.
314F Effluent, old land - - 11.25 a.m. 5th July 1902.	- ditto	- ditto -	- nitto -	+ ·01, – ·001 c.c. At least 100 but less than 1,000.
314H Effluent, new land - - 1 p.m. 8th July 1901.	156,000	1,970	- ditto - -	– ·1 c.c. None in $\frac{1}{10}$ c.c.
317 Effluent, new land - - 11 a.m. 9th July 1901.	360,000	3,000	- ditto - -	- ditto - ditto.
317A General effluent, old land - 11.45 a.m. 9th July 1901.	38,800	460	- ditto - -	+ ·01, – ·001 c.c. At least 100 but less than 1,000.
318 Effluent, new land B - - 10.49 a.m. 10th July 1901.	*See* simple tests	*See* simple tests	- ditto - -	– ·1 c.c. None in $\frac{1}{10}$ c.c.
318A General effluent, old land - 10.30 a.m. 10th July 1901.	- ditto -	- ditto -	- ditto - -	+ ·01, – ·001 c.c. At least 100 but less than 1,000.
318C General effluent, old land - 11.30 a.m. 11th July 1901.	- ditto -	- ditto -	- ditto - -	– ·1 c.c. None in $\frac{1}{10}$ c.c.
318D Effluent, new land B - 11.45 a.m. 11th July 1901.	- ditto -	- ditto -	- ditto - -	- ditto - ditto.
318E General effluent, old land - 10.55 a.m. 12th July 1901.	- ditto -	- ditto -	- ditto - -	+ ·01, – ·001 c.c. At least 100 but less than 1,000.
318F Effluent, new land B - - 11.25 a.m. 12th July 1901.	- ditto -	- ditto -	- ditto - -	– ·1 c.c. None in $\frac{1}{10}$ c.c.
319 Effluent, old land - - 10.15 a.m. 15th July 1901.	- ditto -	369,000	- ditto - -	+ ·01, – ·001 c.c. At least 100 but less than 1 000.
319A General effluent, old land - 10.30 a.m. 15th July 1901.	- ditto -	25,000	- ditto - -	+ ·1, – ·01 c.c. At least 10 but less than 100.
319C Effluent, old land - - 11.30 a.m. 16th July 1901.	- ditto -	140	- ditto - -	- ditto - ditto.
320A General effluent, old land - 11.45 a.m. 17th July 1901.	- ditto -	*See* simple tests	- ditto - -	+ ·01, – ·001 c.c. At least 100 but less than 1,000.
321 Effluent, new land A - - 12.30 p.m. 17th July 1901.	- ditto -	- ditto -	- ditto - -	+ ·1, – ·01 c.c. At least 10 but less than 100.
322A General effluent, old land - 11.15 a.m. 18th July 1901.	- ditto -	- ditto -	- ditto - -	- ditto - ditto.
322 Effluent, new land A - - 11.35 a.m. 18th July 1901.	- ditto -	- ditto -	- ditto - -	+ ·01, – ·001 c.c. At least 100 but less than 1,000.
322B General effluent, old land - 12 noon 19th July 1901.	- ditto -	- ditto -	- ditto - -	- ditto - ditto.
322C Effluent, old land - - 12.15 p.m. 19th July 1901.	- ditto -	- ditto -	- ditto - -	+ ·1, – ·01 c.c. At least 10 but less than 100.
323 Effluent, new land A - 11 a.m. 22nd July 1901.	- ditto -	168,000	- ditto - -	+ ·01, – ·001 c.c. At least 100 but less than 1,000.
323B General effluent, old land - 4.30 p.m. 22nd July 1901.	- ditto -	47,000	- ditto - -	+ ·1, – ·01 c.c. At least 10 but less than 100.
324 Effluent, new land A - - 11.15 a.m 23rd July 1901.	3,520,000	1,760,000	- ditto - -	+ ·01, – ·001 c.c. At least 100 but less than 1,000.
324A General effluent, old land - 11 a.m. 23rd July 1901.	*See* simple tests	*See* sample tests	- ditto - -	+ ·1, – ·01 c.c. At least 10 but less than 100.
Averages - - - (Inclusive of all the effluents)	930,273 [97% reduction]	153,630 [96% reduction]	[Ratio cols. 2 to 3 = 6 : 1]	
Averages - - - (Exclusive of the new land effluents A and B).	183,266 [99% reduction]	37,308 [99% reduction]	[Ratio cols. 2 to 3 = 4·9 : 1]	

[Two samples, 311 and 314, not included in the above table, were also examined. They represented samples of "street washings," collected during a period of heavy rainfall (2nd and 3rd July 1901). Two guinea-pigs were subcutaneously inoculated, the one with 1 c.c. of 311 and the other with 2 c.c. of 314. They both recovered from the effects of the injection].

Diagram 1 shewing as regards (1) total number of bacteria; (2) B. Coli; & (3) Spores of B. Enteritidis sporogenes the results of the bacteriological examination of numerous samples of sewage & of effluents obtained from Aldershot sewage farm.

(The B. enteritidis sporogenes records extend throughout the whole diagram, Where blanks occur as regards the other tests, it will usually be found that these samples were examined by the "gas" & other simple tests & the results are given in detail elsewhere)



§ Signifies "general" effluents
|| " "new" land effluents (A)
¶ " "new" " " (B)

C.S. Signifies "comparative" samples
+ " " "
O " " "

The following is a brief summary of the results shown in Table 1 :—

Crude and Settled Sewage :—

The samples of sewage presented no biological features of special note, beyond the fact that the sewage was a strong one. The *total number of bacteria* was over 10,000,000 (gelatine at 20° C.), and usually between 1 and 10 million (agar at 37° C.) per c.c. *B. coli* numbered at least 100,000 per c.c. *B. enteritidis sporogenes* in nine of the samples was found to be 1,000, but less than 10,000 ; in two samples at least 100, but less than 1,000, and in two samples at least 10,000 (an exceptionally high figure), but less than 100,000 per c.c. As judged by this test the sewage was certainly strong.

Effluents :—

The effluents varied much in their biological qualities, as the following brief summary shows :—

Total number of bacteria (gelatine at 20° C.) per c.c. :—In one sample the number was over 10,000,000. In three samples between 1 million and 10 million. In ten samples between 100,000 and 1,000,000. In six samples between 10,000 and 100,000. In three samples between 1,000 and 10,000. [Provisional standard, less than 100,000 per c.c.]

Total number of bacteria (agar at 37° C.) per c.c. :—In two samples between 1 million and 10 million. In four samples between 100,000 and 1,000,000. In eight samples between 10,000 and 100,000. In five samples between 1,000 and 10,000. In nine samples between 100 and 1,000. [Provisional standard, less than 10,000 per c.c.]

B. coli (and closely allied forms) per c.c. :—In three samples 10,000. In five samples 1,000. In two samples 100. In three samples 10. In one sample 1. In one sample less than 100. [Provisional standard, less than 1,000 per c.c.]

Spores of B. enteritidis sporogenes per c.c. :—In two samples 1,000 not 10,000 ; in fourteen samples 100 not 1,000 ; in eighteen samples 10 not 100 ; in two samples 1 not 10 ; in eleven samples none in $\frac{1}{10}$ c.c. [Provisional standard, less than 10 per c.c.]

2. *Diagram* 1, *illustrating the results shown in Table* 1, *with Comments thereon.*

The results are shown in graphic form in Diagram 1.

By referring to Diagram 1, it will be seen that certain horizontal lines are drawn indicating provisional standards (non-drinking water streams).

All samples, which according to these standards, did not fulfil the following requirements would be tentatively condemned :—

(1.) Total number of bacteria (gelatine at 20° C.) less than 100,000.
(2.) Total number of bacteria (agar at 37° C.) less than 10,000.
(3.) B. coli less than 1,000 - - - - - -
(4.) B. enteritidis sporogenes less than 10 - - -

} per c.c.

As regards (1) 9 out of 23 effluents "passed" the above standard. (8 out of 12, exclusive of the new land effluents A. and B.).

As regards (2) 14 out of 28 effluents "passed" the above standard. (11 out of 16, exclusive of the new land effluents A. and B.).

As regards (3) 7 out of 15 effluents "passed" the above standard. (6 out of 9, exclusive of the new land effluents A. and B.).

As regards (4) 13 out of 47 effluents "passed" the above standard. (4 out of 28, exclusive of the new land effluents A. and B.).

Assuming these standards to be reasonable, it is obvious that a majority of the effluents were unsatisfactory, if all the effluents be considered together, but a minority if the new land effluents A. and B. be excluded. Nevertheless, the B. enteritidis sporogenes test yielded worse results with the old land than with the new. The variable biological characters of the various effluents was noteworthy.* Some were nearly as impure as raw sewage, others showed a high degree of purification. The average results, if not altogether satisfactory, showed, at all events, that land treatment can

* Effluents from land usually yield more variable results than effluents from bacteria-bed processes of sewage treatment.

greatly reduce the number of bacteria in sewage. The results seem to indicate that a broad parallelism (the tests, of course, "run" at different levels) exists between the number of bacteria, B. coli and spores of B. enteritidis sporogenes. But it is also certain that to place too much reliance on this seeming agreement would sometimes lead to error. The records do not seem to show that any selective process was in operation as a result of the land treatment. But it would be unwise to contend from this that no selective process was really in operation.

The strength of the sewage, the fine sandy character of the soil, and the fact that the effluents had percolated through the soil combined to encourage the formation in the soil and retention in the effluents of carbonic acid. This is well shown in the results of Dr. McGowan's analyses* ; and the question arises how far the presence of carbonic acid in the soil and in the effluents would be likely to inhibit the growth or destroy the vitality of the sewage microbes. No definite opinion can be expressed on this point beyond saying that, judging from the results of the bacteriological examination of the effluents, the restraining influence of the carbonic acid could not have been very great.

Taking the B. enteritidis sporogenes results, since they are most numerous, as an index of purification, it may be said that in the majority of cases the land failed to effect a reasonable degree of purification. Thus, 34 out of 47 samples were condemned by the B. enteritidis sporogenes test. Nevertheless, it must be remembered that the sewage was rich in the spores of this pathogenic anærobe. Moreover, although only 13 out of 47 samples were satisfactory, no less than 18 additional samples came within measurable distance of passing the standard provisionally laid down as practicable.

It is probable that land of the kind characteristic of Aldershot Camp sewage farm might be relied on *uniformly* to produce an effluent passing the standards already suggested if it is not overworked,—if, in short, the area of land available is in proper proportion to the amount of sewage being treated. It may, however, be contended that to increase the area of land under sewage treatment so as to bring the average results up to the standard suggested is an impracticable measure, and is merely another way of asserting that the quality of the land at Aldershot is not satisfactory. Against this view, it may be pointed out that no less than 31 out of 47 samples under the existing conditions either "passed" or came within measurable distance of "passing" the standard suggested as regards the B. enteritidis sporogenes test, namely, a negative result with $\frac{1}{10}$ c.c. Moreover, it will be shown presently that the effluents as judged by other tests were far more satisfactory.

3. *Results considered in connection with Mr. Kershaw's Notes.*†

In most cases, when the effluent was unsatisfactory, Mr. Kershaw's notes throw much light on the probable cause. If it be considered that 100 to 1,000 spores of B. enteritidis per c.c. indicates a specially bad effluent, then it is to be noted that the following samples come under this category, namely, 82, 84, 87, 305, 312, 314C, 314F, 317A, 318A, 318E, 319, 320A, 322, 322B, 323, 324.

82, 84, and 87 were from the new land A. (3-acre plot), and it is obvious from Mr. Kershaw's notes that the conditions during the period were most unsatisfactory.

305 was from the old land, and Mr. Kershaw notes that it smelt, and that the sewage fungus was present.

312 was clearly mixed with untreated sewage.

314C and 314F were from the old land, and from his notes Mr. Kershaw evidently regarded them as unsatisfactory.

317A, 318A, 318E were general effluents from the old land. As regards

* Part II. Chemical Report, by Dr. G. McGowan.
† Addendum E, page 32.

the first two, Mr. Kershaw noticed that although they were relatively free from suspended matter, they had a sea-weed smell. 318E contained more suspended matter, due seemingly to increased flow and scouring action.

319 was from old land and contained a good deal of suspended matter.

320A was a general effluent from old and new land, and this sample was fairly clear on inspection.

322 was from new land A, and Mr. Kershaw notes that the effluent was of a deep yellow colour, and contained much suspended matter.

322B was a general effluent from old land, and the amount of suspended matter was noticeable.

323 and 324 were from "new" land A, and obviously the land was not working under satisfactory conditions.

As regards the "good" effluents (those yielding a negative result with 1-10th c.c.), it is noteworthy that the great majority were from the "new" land B. Their numbers were 307, 313, 314A, 314D, 314H, 317, 318, 318D, and 318F. In most cases the land had been treated with sewage for some time, and it is quite possible, as Mr. Kershaw tentatively suggests, that up to a certain point land may daily increase in purifying power. Possibly also the land being "new" had not become saturated, as it were, with sewage microbes, and a mechanical, and to some extent a temporary, separation of the bacteria was taking place. Mr. Kershaw notes that a number of these samples were of a yellow colour and had a sea-weed smell. As regards the other samples yielding a negative result (–0·1 c.c. B. enteritidis sporogenes), one (52) was from an unchalked plot of land, and represented what Mr. Kershaw considered a fair sample of the yield of effluent from the farm during a period of wet weather. Two others (247 and 314E) were from the old land, and one (318C) was an example of a general effluent.

4. *Results in relation to tests other than the B. enteritidis sporogenes test.*

Up to the present, the records as regards B. enteritidis sporogenes have chiefly been considered, and it is necessary to make a few brief remarks in relation to the other tests.

As regards the total number of bacteria (gelatine at 20° C. and agar at 37° C.), the averages in the sewage and effluents are noteworthy. These may be stated as follows :—

———	Gelatine at 20° C. Microbes per c.c.	Agar at 37° C. Microbes per c.c.	Ratio.
Sewages - - - -	33,618,000 - -	4,883,633 - -	6·9 : 1
Effluents (all inclusive) - -	930,273 {Reduction, 97 %}	153,630 {Reduction, 96 %}	6·0 : 1
Effluents (exclusive of the new land effluents A and B.)	183,266 {Reduction, 99 %}	37,308 {Reduction, 99 %}	4·9 : 1

These figures undoubtedly represent a high percentage degree of purification, but when the actual number of microbes remaining in the effluent is so large, percentage purification in an unreliable index of harmlessness. The sewage, it is true, is a very strong one, but it would be inadvisable to urge, for this reason, the adoption of a more lenient standard. Sewage purification processes ought to be judged by actual results, not by percentages. It is worth noting that the ratio of the bacteria growing in agar at 37° C., as compared with those growing in gelatine at 20° C., was not, on the average, diminished in the effluent as contrasted with the raw sewage. Indeed, the ratio in the sewage was roughly, 1 : 7, and in the effluents 1 : 6, inclusive of all the effluents, and 1 : 4·9, exclusive of the new land effluents. This would seem to be an unsatisfactory feature of the biological results; but averages are often misleading, and, on the whole, the results seem to indicate that, in

the case of bad effluents, the two sets of figures tended to converge, and in the case of good effluents to diverge. That is, that in the former event the ratio was a small one, and in the latter more or less pronounced.*

Reverting once more to averages, the figures 930,273 (gelatine at 20° C.) and 153,630 (agar at 37° C.) microbes per c.c., do not seem to indicate that land of the nature available at Aldershot could not possibly be worked so as uniformly to yield an effluent passing the standards suggested, namely, less than 100,000 and 10,000 bacteria per c.c. at 20° C. and 37° C. respectively. It is significant that, as regards the gelatine at 20° C. figures, three samples contained less than 10,000, and six other samples less than 100,000, out of a total of 23 effluents. As regards the records of growth in agar at 37° C. no fewer than nine samples contained less than 1,000, and five other samples less than 10,000 bacteria per c.c. out of a total of 28 effluents. Moreover, if we exclude the new land effluents A and B, the figures are still more satisfactory, viz., 183,266 (gelatine at 20° C.) and 37,308 (agar at 37° C.) microbes per c.c.

The B. coli records are of interest, since no fewer than seven out of 15 samples (six out of nine, exclusive of the new land effluents A and B) contained less than 1,000 B. coli in 1 c.c. As the crude sewage contained at least 100,000 per c.c., these results show that a great reduction had taken place.

As regards the indol test (indol in broth cultures, five days at 37° C.), the results show a broad parallelism with the B. coli records. Here the standard suggested is a negative result with ·001 c.c. (less than 1,000 indol-producing bacteria per c.c.) of the sample,

Samples of sewage, namely, 48, 50, 54, 81, 86, 302, 303, 306, all gave a positive result with ·00001 c.c.

Effluents,	49, 51, and 55,	a positive result	with		·1 c.c.
,,	52, 49, 304	,,	,,	,,	·01 c.c.
,,	53, 82, 83	,,	,,	,,	·001 c.c.
,,	56, 84, 87, 88, 305	,,	,,	,,	·0001 c.c.
,,	307, negative result with ·01 c.c.				

Seven out of 15 samples of effluent passed the standard of a negative result with ·001 c.c.

In connection with this test, I may point out that on more than one occasion I have obtained a negative result when using for cultural purposes the bacterial contents of 100 c.c. of a pure water. Comparison of this with the above records as regards crude sewage, namely, a positive result with ·00001 c.c. shows a strong contrast.

In the table and diagram illustrating Appendix III. (page 196), the results as regards the "gas" and B. enteritidis sporogenes tests are compared. The results are interesting, inasmuch as the effluents were much more satisfactory when judged by the former as compared with the latter test. Thus, as regards the "gas" test, no less than 35 out of 46 samples "passed," whereas only 13 out of a similar number were satisfactory as regards the B. enteritidis sporogenes test. From Mr. Kershaw's notes, it appears not improbable that the presence of an undue amount of suspended matter in many of the effluents was responsible for the relatively high figures, as regards B enteritidis sporogenes. It is not improbable that effluents containing much suspended matter are apt to yield, as regards B. enteritidis sporogenes, higher results than as regards the "gas" and other tests. But too much stress must not be laid on this view, as it is largely a matter of conjecture. Another interpretation which might be placed on these results, is that relatively more bacilli than spores were destroyed in the process of purification. If any absolute proof could be furnished of the truth of this not unlikely supposition, it would be of considerable interest from the epidemiological point of view. The fact that the sewage seemed to be more than usually rich in the spores of B. enteritidis sporogenes, however, must not be ignored.

---

* In the London County Council experiments, the ratios of the total number of bacteria growing (a) in gelatine at 20° C. and (b) in agar at 37° C. was 1·74 : 1, in the case of Crossness crude sewage and 1·66 : 1 as regards the 13-ft. coke-bed effluent.

In the table and diagram illustrating Appendix VI. (page 212) (*see* also Addendum C.) the results as regards the litmus milk and neutral-red broth tests are brought into comparison with the "gas" and B. enteritidis sporogenes test. It appears that 15 out of 33 samples "passed" the litmus milk test and 19 out of 35 the neutral red broth tests.

The "gas," B. enteritidis sporogenes and neutral-red broth tests were also used for a special series of experiments set forth in Addendum A, Table 3. Ten, three and four out of 15 effluents, passed respectively the standards set up for these tests.

5. *Grouping of the effluents based on Mr. Kershaw's Notes.*

Passing next to the consideration of Mr Kershaw's notes and tables dealing with the various samples, with the view of grouping the various effluents, the following points are worthy of note :—

The following samples shown in Table 1 and Diagram 1 come under the category of "general" or "combined" effluents, namely, 53, 56, 89, 246, 317A, 318A, 318C, 318E, 319A, 320A, 322A, 322B, 323B, 324A. Of these only one (318C) "passed" the standard as regards B. enteritidis sporogenes, but eight others (53, 56, 89, 246, 319A, 322A, 323B, 324A) were fairly satisfactory effluents. Judged by the sum of all the biological tests, these "general" effluents were unsatisfactory, but not, as a rule, to a conspicuous extent. A number of them "passed" the majority of the tests employed.

Samples 321, 322, 323, and 324 (Table 1, Diagram 1) were not satisfactory. They were obtained from the new land A after it had been in operation for a prolonged period, and this might have been considered a sufficient explanation of the results, if it were not for the fact that samples obtained still later (461, 463, 465, Addendum D) yielded in most respects remarkably good results.

The following samples (Table 1, Diagram 1) were from the "new" land, namely: 82, 83, 84, 87, 88, from the new land A during the earlier period of its history; and 307, 312, 313, 314A, 314D, 314H, 317, 318, 318D, 318F, from the "new" land B. Some of these samples were undeniably bad, but a number of them were distinctly good effluents. Thus no less than nine (all, however, from the "new" land B) "passed" when judged by the B. enteritidis test.

Samples 49, 51, 52, 53, 55, 56, 89, 246, 247, 304, 305, 314B, 314C, 314E, 314F, 317A, 318A, 318C, 318E, 319, 319A, 319C, 320A, 322A, 322B, 322C, 323B, and 324A were from the "old" land. They varied very greatly in their biological composition, and only four of them "passed" the B enteritidis sporogenes test, although 13 others came within measurable distance of "passing," and a fair proportion of these effluents proved satisfactory when judged by other tests.

As regards "corresponding"* samples of sewage and effluent (48 and 49, 50 and 51, 54 and 55, 302 and 304, 303 and 305, 81 and 82, 86 and 87, 306 and 307, 314G and 314H), the results show that in some cases the percentage improvement in the effluent, as compared with the raw sewage, was noteworthy, in other instances disappointing, but taking the majority of cases fairly satisfactory.

The "comparative"† samples were as follows: (51 and 55), (314C and 314E), (82, 83, 84, 87, 88), (321, 322, 323, 324), (307, 312, 313, 314A, 314D), (314H, 317, 318, 318D, 318F). In not a few cases, they illustrate in a striking manner the lack of uniformity of results of the bacteriological examination of effluents collected from time to time from the same plot of land. For

---

* That is "corresponding," in the sense that the effluent from the land was collected at such a time after the application of the sewage to the plot of land as seemingly to represent the degree of purification of the sewage effected by the land treatment. It appears, however, from Dr. McGowan's chemical records that the correspondence was often more apparent than real.

† "Comparative," inasmuch as the effluents in each series were collected from the same plot of land.

further details, reference must be made to Addendum E.; and as regards the distinction between the old land effluents and the new land effluents A and B, to the reports of Mr. Kershaw and Dr. McGowan (Parts II. and IV.).

6. *Results of the bacteriological examination of additional samples of river water, subsoil water, and "street washings," with accompanying table.*

In Table 2, the results of the bacteriological examination of samples of river water, subsoil water, "street washings" are shown.

The impure state of the river water, above the junction of the sewage effluent, limits the usefulness of the results obtained by the examination of samples 56, 57, 58, and 59. Moreover, to obtain results of value, multiple samples would require to be examined. It is probable, however, that from the chemical point of view the examination chemically of even isolated samples would yield useful information. The samples were examined bacteriologically mainly with the object of obtaining bacteriological records to run parallel with Dr. McGowan's chemical results. The ratio of the effluent to river water is about 1 to 6.

It is worth noting that the river water (57) although impure was much purer than the effluent (56) and that the mixed river water and effluent, although it contained much fewer bacteria than the effluent alone (56), at a point just below the junction of the effluent with the river (58), seemingly deteriorated (so far as the total number of bacteria are concerned) in biological quality some 500 feet lower down (59). Mr. Kershaw, always careful to note any circumstance which might have a bearing on the chemical or bacteriological results, observes in his "additional notes on samples" that some cattle had apparently been in the stream some hours previous to drawing the sample.

As regards samples of river water, numbers 326 and 327, it is of interest to note that Mr. Kershaw speaks of these samples as presenting a somewhat similar appearance, except that, if anything, 327 seemed to be the clearer. The bacteriological examination showed that the two samples were very similar in their biological composition, notwithstanding the fact that 326 was collected above and 327 below the effluent outfall. The river, however, was in flood, and I have frequently had occasion to note the unsatisfactory bacteriological results yielded by flood waters.

Sample 60 was from a pump well near the farm. It contained 720 bacteria per c.c. (gelatine at 20° C.) and 38 microbes in 1 c.c. (agar at 37° C.); no B. coli in 1 c.c. and no spores of B. enteritidis sporogenes in 10 c.c.

Many samples of drinking water may be found to be much purer than this; nevertheless, the wide distinction between the biological composition of this water and most of the effluents from the Aldershot Camp sewage farm is striking. On many sewage farms, a good deal of subsoil water finds its way into the under-drains. It seemed, therefore, desirable to take the opportunity, whenever it presented itself, of examining, for comparative purposes, samples of subsoil water and well water.

The results of the examination of samples 311 and 314 is of interest as showing that "street washings" may be nearly, if not quite, as impure as crude sewage. The samples were collected respectively after two and three days' heavy rain, and so, as Mr. Kershaw observes, were probably as pure as they could be expected at any time to be. As regards the latter sample, however, there was a suspicion of some slight admixture of sewage escaping from the farm.

The question of the advantages of the so-called "separate system" is one which merits serious attention from the bacteriological point of view.

Guinea-pigs inoculated subcutaneously with comparatively small quantities of samples of "street washings" have usually either rapidly succumbed, or at least shown signs and symptoms of being injuriously affected Nevertheless, as regards samples 311 and 314, two guinea-pigs inoculated subcutaneously the one with 1 c.c. of 311 and the other with 2 c.c. of 314 eventually recovered completely, although both showed signs of a local reaction.

TABLE 2.—Showing the results of the bacteriological examination of samples of river water, subsoil water, street "washings," obtained from Aldershot Sewage Farm.

Description of the Sample.	Total Number of bacteria per c.c.		Number of B. coli (or closely allied forms) per c.c.	Number of Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in milk culture) per c.c.
	Gelatine at 20° C.	Agar at 37° C.		
*56 General effluent before entering Blackwater River. 27th March 1900, 12.15 p.m.	410,000	16,000	1,000 not 10,000 - (indol + ·0001 c.c.)	+ ·1 – ·01 c.c. At least 10 but less than 100.
*57 Blackwater River water, above junction with effluent. 27th March 1900, 12.30 p.m.	8,200	500	At least 10 - - (indol + ·1 c.c.)	+ ·1 c.c. At least 10.
*58 Blackwater River water, just below junction of effluent. 27th March 1901, 12.45 p.m.	26,000	4,300	At least 100 - - (indol + ·01 c.c.)	+ ·1 – ·01 c.c. At least 10 but less than 100.
*59 Blackwater River water, 500 feet below junction with effluent. 27th March 1900, 1.15 p.m.	40,000	5,200	At least 100 - - (indol + ·01 c.c.)	+ ·1 c.c. At least 10.
†60 Subsoil water - - - 2nd April 1900, 12 noon.	720	38	None in 1 c.c. - (indol + 1 c.c.)	None in 10 c.c.
‡311 Street "washings" - - 2nd July 1901, 12.45 p.m.	7,500,000	640,000	*See* tests below -	+ ·1, – ·01 c.c. At least 10 but less than 100.
‡314 Street "washings" - - 3rd July 1901, 11.45 a.m.	22,800,000	900,000	- ditto - -	+ ·01, – ·001 c.c. At least 100 but less than 1,000.
‡326 Blackwater River water, 30 yards above effluent outfall. 24th July 1901, 10.45 a.m.	*See* tests below.	*See* tests below.	*See* tests below -	+ ·1, – ·01 c.c. At least 10 but less than 100.
‡327 Blackwater River water, 30 yards below effluent outfall. 24th July 1901, 11 a.m.	- ditto -	- ditto -	- ditto - -	- ditto - ditto.

* Samples 56, 57, 58, and 59 gave as regards "gas" in gelatine "shake" cultures (48 hours at 20° C.) the following results: 56, + ·01 c.c.; 57, + 1, – ·1 c.c.; 58, + ·1, – ·01 c.c.; 59, + ·1 c.c.

† Sample 60 gave as regards "gas" in gelatine "shake" cultures (48 hours at 20° C.) the following result: negative result, 1 c.c.

‡ Samples 311, 314, 326, and 327 gave as regards the neutral red broth (24 hours at 37° C.), litmus milk (24 hours at 37° C.) and "gas" (24 hours at 20° C.) tests, the following results:—

Neutral red broth test:—
311 + ·0001 – ·00001 c.c.
314 + ·00001 c.c.
326 + ·01 – ·001 c.c.
327 + ·01 – ·001 c.c.

Litmus milk test:
311 Acid solid clot ·001, acid no clot ·0001 and ·00001 c.c.
314 Acid clot ·0001, acid no clot ·00001 c.c.
326 Acid clot ·1, acid no clot ·01 and ·001, negative ·0001 c.c.
327 Acid clot ·01, acid no clot ·001 and ·0001 c.c.

"Gas" test:
311 + ·001 – ·0001 c.c.
314 + ·001 – ·0001 c.c.
326 + ·1 – ·01 c.c.
327 – ·1 c.c.

7. *General Conclusions.* §

The results, as a whole, do not suggest the impracticability of land similar to that at Aldershot Camp sewage farm being worked so as uniformly to produce an effluent which would pass the provisional standards that have been tentatively suggested. In this connection, it is noteworthy that as regards most, at all events, of the tests employed, a number of the effluents not only "passed," but easily "passed" the respective standards for non-drinking water streams. Moreover, a majority, not a minority, of the effluents either "passed" or came within measurable distance of "passing" the standards set up for the various tests. But obviously it would be necessary to alter, in some way or other, the existing methods of working the farm or else to acquire an additional area of land, in order to obtain uniformly satisfactory results.

From Mr Kershaw's notes, it appears that the farm is well managed. It follows from this that either an additional area of land would be required to

§ For statistical information, see tabular statement at the beginning of this report, Section I.

produce a uniformly satisfactory effluent or else that the standards suggested require modification. As regards the latter point, it is desirable to point out in as emphatic a manner as possible that the suggested standards are merely provisional for working and comparative purposes, and need not necessarily be adopted, as they stand, without modification.

Nevertheless, as regards the B. enteritidis sporogenes test, some exercise of judgment would be required in interpreting the general results. The better results yielded by the other tests modify considerably the unfavourable impression left by the unsatisfactory results yielded by the B. enteritidis sporogenes test. But it has never been suggested that, because an effluent fails as regards a single test, the results yielded by other tests should therefore be ignored. It is not improbable that the strength of the sewage, the length of time the farm has been in operation, the fact that the sludge is ploughed into the land, and the hardy nature of spores as compared with bacilli, may account for the results being seemingly less satisfactory with the B. enteritidis sporogenes test than with the other tests employed in the investigation.

It is perhaps hardly necessary to add that, considered from the bacteriological point of view, none of the samples of effluent were in a fit state to be turned into a drinking-water stream.

The truth of this proposition may be judged from a comparison of these results with those obtained in the bacterioscopic examination of potable waters. Thus pure water may contain less than 100 microbes per c.c. No B. coli, it may be, in 1, 10, or even 100 c.c. or more of the water. And no spores of B. enteritidis sporogenes in from 100 to 500 c.c.

These general conclusions are based on the results set forth in the Addenda as well as on those already considered in detail.

Addendum A.—*Results of the examination by means of simple tests of samples obtained from Aldershot Camp Sewage Farm. (Special Comparative Series of Experiments.)*

It was the wish of the Commission that some experiments should be carried out with simple tests. Tests which, although perhaps not invariably infallible, nevertheless afford a fair indication of the probable biological qualities of sewage effluents, and tests, moreover, which could be readily carried out by comparatively speaking inexperienced workers. With this end in view, a special series of experiments was carried out in connection with Aldershot, Nottingham, Leicester, and Beddington sewage farms.

The results, in so far as they apply to Aldershot, are shown in Table 3, Diagram 2 (*see* also Appendix II., page 194).

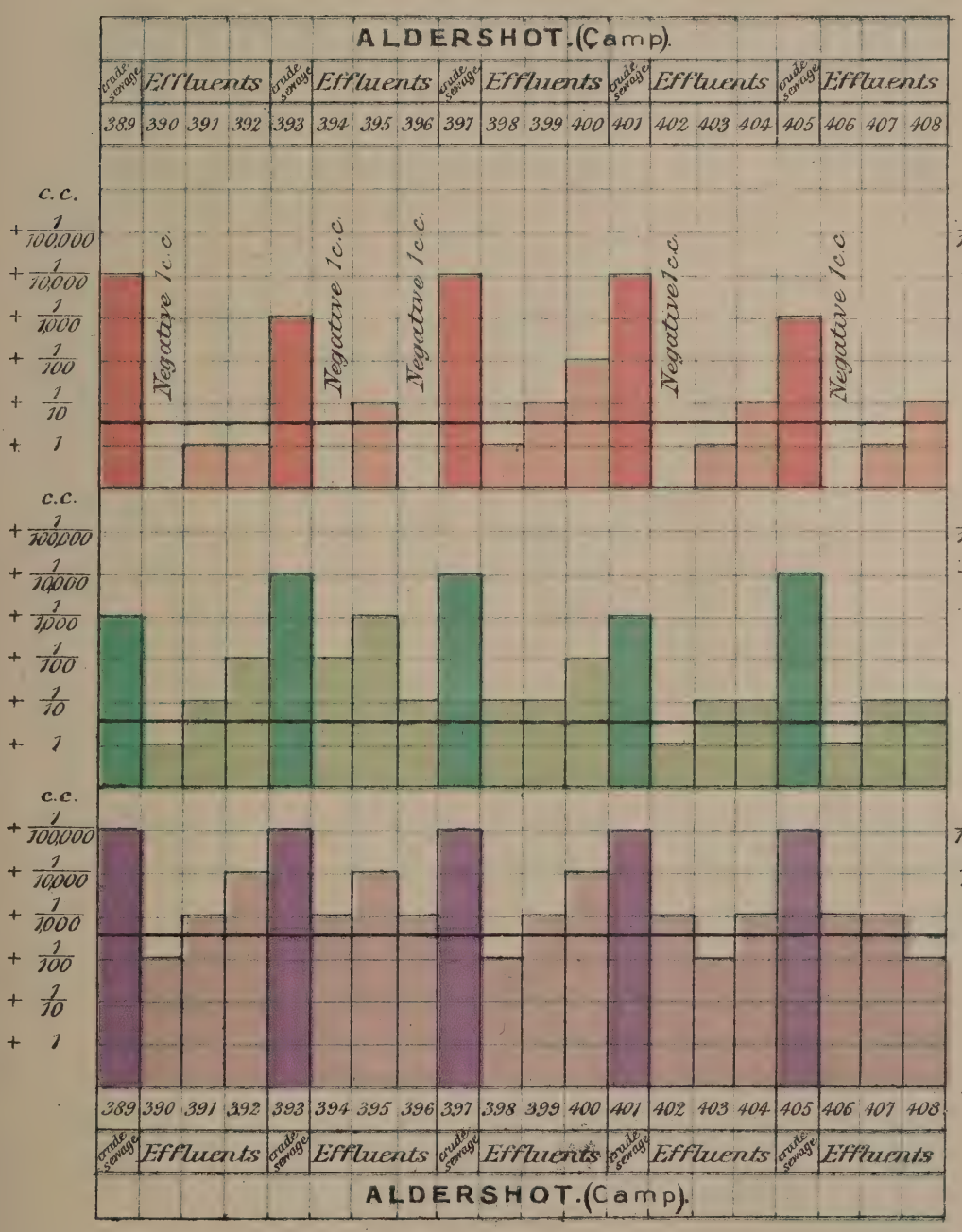
The tests employed were (1) the "gas," (2) B. enteritidis sporogenes, and (3) neutral-red broth tests. It has already been pointed out to the Commission that (1), the first-named test, gives an indication of the number (relative, not actual) of gas-forming bacteria in effluents which belong, for the most part, to the objectionable B. coli and B. proteus class. (2) The B. enteritidis sporogenes test, apart from its specialised value, is of great importance as an extremely simple method of measuring the probable number of anærobic micro-organisms of all sorts present in a sample. (3) The neutral-red broth test yields results which run nearly parallel with the records as regards B. coli.

The standards suggested as regards these three tests are as follows :—

(1) "Gas" test (24 hours at 20° C.) -	Negative result, 0·1 c.c. (less than 10 per c.c.
(2) B. enteritidis sporogenes test -	Negative result, 0·1 c.c. (less than 10 per c.c.).
(3) Neutral-red broth test - -	Negative result, ·001 c.c. (less than 1,000 per c.c.).

By referring to Table 3 and Diagram 2, it will be seen that 10 out of 15 samples of effluent passed the "gas" test. Only three samples were satisfactory as regards B. enteritidis sporogenes, but eight additional samples came within measurable distance of passing the standard suggested. The sewage was rich in the spores of the anærobic, but the gas-forming bacteria were also very numerous ; and there is more than a probability that

Diagram 2 showing, as regards the (a) "gas"; (b) B. enteritidis sporogenes; & (c) neutral red broth tests, the results of the bacteriological examination of five samples of sewage & fifteen samples of effluent obtained from Aldershot sewage farm.



10.02.

Weller & Graham Ltd Litho London

TABLE 3.—Showing as regards the (a) "Gas"; (b) B. enteritidis sporogenes; and (c) Neutral-red broth tests, the results of the bacteriological examination of five samples of sewage and fifteen samples of effluent obtained from Aldershot Camp Sewage Farm.

[The double line in each case refers to a provisional standard (non-drinking water streams). The sign + occurring on the right hand side of this line means that the effluent is condemned on the basis of this standard.]

Description of Sample.	"Gas" in gelatine "shake" cultures (24 hours at 20° C.)						Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk culture).						Neutral-red broth test (24 hours at 37° C.) Greenish yellow fluorescence = positive result. No change in colour = negative result.						Sewage Farm.
	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	
389. *Crude Sewage.*—Stanhope Lines (12.15 p.m., 14th October 1901, air 57° F., Sample 57° F.)					+					+	−							+	Aldershot Camp.
390. General effluent (12.30 p.m., 14th October 1901, air 57° F., Sample 54° F.)	−						+	−							+	−			
391. Final effluent from rye grass (1 p.m., 14th October 1901, air 57° F., Sample 54° F.)	+	−						+	−							+	−		
392. Final effluent from rye grass (1.30 p.m., 14th October 1901, air 56° F., Sample 53° F.)	+	−							+	−							+		
393. *Crude Sewage* (10 45 a.m., 15th October 1901, air 58° F., Sample 56° F.)				+	−						+							+	
394. Final effluent from rye grass (11.30 a.m., 15th October 1901, air 59° F., Sample 55° F.)	−								+	−						+	−		
395. Final effluent from rye grass (12 noon, 15th October 1901, air 57° F., Sample 55° F.)		+	−							+							+		
396. General effluent (11.10 a.m., 15th October 1901, air 58° F., Sample 54° F.)	−							+	−							+	−		
397. *Crude Sewage* from Stanhope Lines (10.30 a.m., 16th October 1901, air 52° F., Sample 56°F.)					+	−					+							+	
398. General effluent (11 a.m., 16th October 1901, air 53° F., Sample 54° F.)	+	−						+	−						+	−			
399. Final effluent from rye grass (11.30 a.m., 16th October 1901, air 52° F., Sample 54° F.)		+	−					+	−							+	−		
400. Final effluent from rye grass (12 noon, 16th October 1901, air 52° F., Sample 54° F.)			+	−					+	−							+		
401. *Settled Sewage* from Stanhope Lines (10.15 a.m., 17th October 1901, air 52° F., Sample 56° F.)					+					+	−							+	
402. General effluent (10.40 a.m., 17th October 1901, air 52° F., Sample 53° F.)	−						+	−								+	−		
403. Final effluent from rye grass (11.5 a.m., 17th October 1901, air 51° F., Sample 53° F.)	+	−						+	−						+	−			
404. Final effluent from rye grass (11.20 a.m., 17th October 1901, air 51° F., Sample 52° F.)		+	−					+	−							+	−		
405. *Settled Sewage* from Stanhope Lines (10 a.m., 18th October 1901, air 54° F., Sample 56° F.)				+	−						+	−						+	
406. Final effluent from rye grass (10.30 a.m., 18th October 1901, air 54° F., Sample 54° F.)	−						+	−								+	−		
407. General effluent (10.50 a.m., 18th October 1901, air 54° F., Sample 54° F.)	+	−						+	−							+	−		
408. Final effluent from rye grass (11.20 a.m., 18th October 1901, air 54° F., Sample 53° F.)		+	−					+	−						+	−			

the land was removing or destroying the gas-forming bacteria to a greater extent than the spores of B. enteritidis sporogenes. This perhaps is what might have been anticipated; but a fact of interest, in connexion with the bacteriological investigation of different processes of sewage purification, is that, generally speaking, the spores are apt to decline in number, seemingly almost *pari passu* with the reduction in the number of microbes present as bacilli. It is to be noted that Aldershot Camp farm has been in existence for more than 36 years, and that the sludge mixed with farmyard manure is dug or ploughed into the soil. These are circumstances which must be borne in mind in considering the number of spores of B. enteritidis sporogenes in the effluents. Sludge is peculiarly rich in the spores of this pathogenic anærobe, and spores, as compared with bacilli, are extremely hardy. It may be conjectured that the age of the farm and the utilisation of the sludge for farming purposes may possibly, to some extent, have influenced the results as regards B. enteritidis sporogenes. Nevertheless, probably the main factor at work in bringing about the observed results was the great number of spores in the sewage. Four samples proved satisfactory, as judged by the neutral red broth test, but eight other samples were fairly satisfactory. The diagram shows that a broad parallelism exists between the results yielded by the use of the above three tests.

Further and separate records will be found in Addenda B. and C.

Addendum B.—*Comparative records as regards* (a) *the "gas" and* (b) *B. enteritidis sporogenes tests of samples obtained from Aldershot Camp as well as other sewage farms.*

These results are shown in the table and diagram illustrating Appendix III. (page 196), and they include all the samples (from other sewage farms as well as Aldershot Camp) which were examined by both of these tests. These records are additional to the special series already described in Addendum A., and they deal in all with 194 samples. As explained in a previous section (section 4) 35 out of 46 samples obtained from Aldershot were satisfactory as regards the "gas" test (negative result 0·1 c.c.), but only 13 out of a similar number passed the B. enteritidis sporogenes standard (negative result 0·1 c.c.) In considering these tables and the accompanying diagram, special attention should be directed to the fact that the two tests show results broadly parallel. The marked percentage purification effected by the land treatment in many cases is also noteworthy. Further, the distinction between, on the one hand, crude sewage and effluents showing an average degree of purification and, on the other hand, waters of potable sort, is worthy of serious attention. As regards the former (sewage and effluents), the records speak for themselves; as regards the latter it has been pointed out from time to time that pure water may yield a negative result as regards the "gas" test, even when the bacterial contents of 200 c.c., and in respect of the B. enteritidis sporogenes test as much as 500 c.c., are used for cultural purposes.

This table and diagram (Appendix III.) will be referred to again, as they deal in all with other effluents besides those obtained from Aldershot Camp sewage farm.

Addendum C.—*General comparison, as regards* (a) *the "gas,"* (b) *B. enteritidis sporogenes,* (c) *neutral red broth, and* (d) *litmus milk tests of samples obtained from Aldershot Camp as well as other sewage farms.*

These results are shown in the table and diagram illustrating Appendix IV. (page 203), and they include all the samples (from other sewage farms as well as Aldershot Camp) which were examined by practically all of these tests. These records are separate from and additional to the special series described in Addendum A., and they deal in all with 63 samples.

As explained in a previous section (section 4) 15 out of 33 samples of the Aldershot effluent passed the litmus milk test* and 19 out of 35 the neutral.

* The provisional standard here suggested is a negative result as regards the formation of acid and clot in milk, when using for cultural purposes 0·01 c.c. Since writing this report (1901), the composition of the medium has been altered and the standard raised to the same level as the neutral-red broth test (negative result, – ·001 c.c.). The test is now (1902) known as the litmus milk (modified) test.

red broth test. The same 35 samples examined by the "gas" and B. enteritidis sporogenes tests yielded the following results, namely, 29 samples were considered satisfactory, when judged by the "gas" test, but only 12 passed the B. enteritidis sporogenes standard.

This table and diagram, Appendix IV., will be referred to from time to time, as they deal with other effluents besides those obtained from Aldershot Camp sewage farm.

Addendum D.—*Additional bacteriological notes.*

During the month of October 1901 a few additional samples were examined as regards the number of bacteria and the B. coli and indol tests. The results are shown in the following table :—

Description of the Sample.	Number of bacteria per c.c.		Number of B. coli per c.c.	Indol test (indol in broth cultures, 5 days at 37° C.)
	Gelatine at 20° C.	Agar at 37° C.		
389 Crude sewage - - 14th October 1901.	21,000,000	3,480,000	100,000	+ ·00001 c.c.
390 General effluent - - 14th October 1901.	45,000	8,000	Less than 10,000	+ ·001 ; – ·0001 c.c.
395 Final effluent - - 15th October 1901.	980,000	824,000	At least 1,000	+ ·001 c.c.
396 General effluent - - 15th October 1901.	16,000 [390 and 396 passed the standard of less than 100,000 per c.c.]	2,700 [390 and 396 passed the standard of less than 10,000 per c.c.]	Less than 1,000 [396 passed the standard of less than 1,000 per c.c., and 390 may have done so as it gave a negative result with $\frac{1}{10000}$ c.c.]	+ ·01 ; – ·001 c.c. [396 passed the standard of a negative result with ·001 c.c.]

Streptococci.—Sample 51 (effluent) was examined for the presence of streptococci. But none could be found in 0·1 and 0·01 c.c. of the sample. Unfortunately, during the periods when the Aldershot samples were being received, other tests were being specially investigated and compared with one another, and the streptococcus test was in consequence not employed.

Animal inoculation experiments.—Two guinea-pigs were respectively inoculated subcutaneously with (*a*) 2 c.c. of sample 314 (street "washings") and (*b*) 1 c.c. of sample 311 (street "washings"). Both animals showed signs of a local reaction, but eventually recovered completely from the effects of the injection.

Additional samples from New Land A.—During the early part of the present year (1902) a few additional samples of effluent were examined. They yielded results as follows :—

461. Final effluent, New Land A., 29th January, 1902:
Total number of microbes (gelatine at 20° C.) 22,000 } per c.c.
" " " (agar at 37° C.) - 400 }
B. coli test, negative result $\frac{1}{1000}$ c.c.
Indol test, " " "

463. Final effluent, New Land A., 30th January, 1902:
Total number of microbes (gelatine at 20° C.) 1,100 } per c.c.
" " " (agar at 37° C.) - 40 }
B. coli test, negative result $\frac{1}{10}$ c.c.
Indol test, + $\frac{1}{10}$ c.c. ; – $\frac{1}{100}$ c.c.

465. Final effluent, New Land A., 31st January, 1902:
Bile-salt broth test - } Negative result $\frac{1}{100}$ c.c.
Neutral red broth test - }
B. enteritidis sporogenes test + $\frac{1}{10}$ c.c. ; – $\frac{1}{100}$ c.c.
"Gas" test - - - negative result $\frac{1}{10}$ c.c.

The above samples (461, 463, and 465) yielded, on the whole, remarkably good results. It is difficult to understand why this plot of land should have improved in purifying power to so marked an extent since 23rd July 1901 (sample 324, Table 1, Diagram 1). Mr. Kershaw, however, supplies a note to the effect that probably the very heavy rain, falling at this period (January, 1902) may have considerably diluted the effluent.

Plate I.

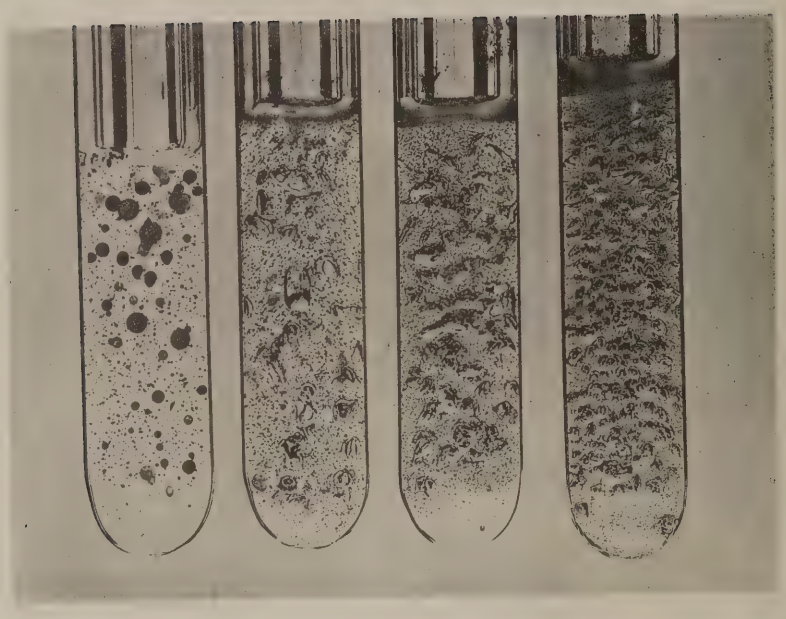


Fig. 1.

Fig. 2.

PLATE I.

Fig. 1.—Aldershot settled sewage, sample 86. Illustrating the "gas" test ("gas" formation in gelatine shake cultures in 24 hours at 20° C.). The tubes, from right to left, contain $\frac{1}{10}$, $\frac{1}{100}$, $\frac{1}{1000}$, $\frac{1}{10000}$ c.c. of the sample. It will be noted that there is gas formation in the first three tubes; the test tube (on the extreme left) shows growth but no gas production. Result, + $\frac{1}{1000}$; − $\frac{1}{10000}$ c.c

[About natural size.]

Fig. 2.—Aldershot final effluent, sample 87, corresponding to sample 86. Illustrating the "gas" test ("gas" formation in gelatine "shake" cultures in 24 hours at 20° C.). The tubes from right to left contain 1, $\frac{1}{10}$, $\frac{1}{100}$, $\frac{1}{1000}$ c.c. of the sample. It will be noted that there is gas formation in the first three tubes; the last tube (on the extreme left) shows growth but no gas production. Result, + $\frac{1}{100}$; − $\frac{1}{1000}$ c.c. That is to say, the effluent (87) is, on the basis of this test, 10 times better than the settled sewage (86).

[About natural size.]

Addendum E.—*Mr. Kershaw's abridged Notes to accompany Bacteriological data.*

ALDERSHOT CAMP FARM.

DOMESTIC SEWAGE.

Number of Sample.	Date of drawing Sample.	Time of day.	Rainfall day previous to drawing Sample.	Rainfall day of drawing Sample.	Air Temperature time of drawing Sample.	Temperature of Sample.	Maximum Temperature during the 24 hours.	Minimum Temperature during the 24 hours.	Humidity (9 a.m.)	Dissolved Oxygen in Sample.	Brief description of Sample.	REMARKS.
	1900:		Inches.	Inches.	°C. °F.	°C. °F.	°C. °F.	°C. °F.		*c.c.s.		
						WINTER VISIT:						
48	12 March -	11 a.m. -	·01	·00	*	8·3 (47)	7·2 (45)	0·00 (32)	—	—	Crude sewage.	*Dissolved Oxygen, humidity, and air temperature were not taken until a later stage.
49	12 ,, -	3.15 p.m. -	·01	·00	—	6·6 (44)	7·2 (45)	0·00 (32)	—	—	Effluent.	
50	14 ,, -	11 a.m. -	·00	·00	—	7·2 (45)	11·6 (53)	3·8 (39)	—	—	Settled sewage.	
51	14 ,, -	3.15 p.m. -	·00	·00	—	6·6 (44)	11·6 (53)	3·8 (39)	—	—	Effluent.	
52	19 ,, -	11.15 a.m. -	(Snow.)† (·30)	(Snow.) (·14)	—	6·6 (44)	10·0 (50)	− 1·1 (30)	—	—	,,	*Mean daily maximum temperature, 9·3 °C. (48·8°) F. Mean daily minimum temperature, − 1·3 °C. (29·5°) F. Mean daily rainfall, ·058 in.
53	19 ,, -	11.30 ,, -	(·30)	·14	—	7·2 (45)	10·0 (50)	− 1·1 (30)	—	—	,,	
54	21 ,, -	1 p.m. -	·00	·29	—	7·2 (45)	6·6 (44)	3·3 (38)	—	—	Settled sewage.	*For the period 10th March to 3rd April 1900.
55	21 ,, -	4 ,, -	·00	·29	—	6·1 (43)	6·6 (44)	3·3 (38)	—	—	Effluent.	
56	27 ,, -	12.15 ,, -	(Snow.) (·05)	(Snow.) (·31)	—	7·7 (46)	7·7 (46)	− 1·8 (29)	—	—	,,	†Samples which may have been affected by rainfall or snow are underlined.
57	27 ,, -	12.30 ,, -	·05	·31	—	5·5 (42)	7·7 (46)	− 1·8 (29)	—	—	River water.	
58	27 ,, -	12.45 ,, -	·05	·31	—	5·5 (42)	7·7 (46)	− 1·8 (29)	—	—	River water and effluent.	
59	27 ,, -	1.15 ,, -	·05	·31	—	5·5 (42)	7·7 (46)	− 1·8 (29)	—	—	,, ,,	
60	2 April -	12 ,, -	·00	·04	—	7·2 (45)	12·7 (55)	− 2·2 (28)	—	—	Subsoil water.	
81	28 May -	11.45 a.m. -	·00	·00	19·4 (67)	14·4 (58)	22·2 (72)	5·5 (42)	—	—	Settled sewage.	*Mean daily maximum temperature, 20·8 °C. (69·5°) F. Mean daily minimum temperature, 6·6 °C. (44°) F. Mean daily rainfall ·017 ins.
82	28 ,,	3 p.m. -	·00	·00	18·8 (66)	11·1 (52)	22·2 (72)	5·5 (42)	—	—	Effluent.	
83	29 ,, -	3.15 ,, -	·00	·00	17·2 (63)	11·6 (53)	20·0 (68)	6·1 (43)	—	—	,,	
84	30 ,, -	3.15 ,, -	·00	·01	17·2 (63)	11·6 (53)	17·2 (63)	7·7 (46)	—	—	,,	
85	31 ,, -	2.45 ,, -	·01	·09	10·5 (51)	11·6 (53)	12·7 (55)	11·1 (52)	—	—	,,	
86	5 June -	12.45 ,,	·00	·00	14·4 (58)	15·5 (60)	23·8 (75)	3·8 (39)	—	—	Settled sewage.	
87	5 ,, -	3 . -	·00	·00	14·4 (58)	12·2 (54)	23·8 (75)	3·8 (39)	—	—	Effluent.	

88	6 ,,	3.15 ,,	·00	·00	16·1 (61)	12·7 (55)	27·2 (81)	10·0 (50)	—	—	Effluent	*For the period 24th May, 1900, to 6th June, 1900.
89	6 ,,	2.30 ,,	·00	·00	16·6 (62)	12·2 (54)	27·2 (81)	10·0 (50)	—	—	,,	
90	7 ,,	3.15 ,,	·00	·00	14·4 (58)	17·2 (63)	—	—	—	—	,,	
	1901:											
245	1 April	2 p.m.	Heavy rain.	·00	10·5 (51)	9·4 (49)	—	—	—	—	Settled sewage.	
246	1 ,,	2.15 ,,	,,	·00	10·5 (51)	5·5 (42)	—	—	—	—	Effluent.	
247	1 ,,	3 ,,	,,	0·0	10·0 (50)	5·5 (42)	—	—	—	—	,,	
302	19 June	11.5 a.m.	·00	·05	18·8 (66)	20·0 (68)	23·8 (75)	10·5 (51)	94*	—	Settled sewage	*Saturation = 100.
303	19 ,,	11.30 ,,	·00	·05	17·7 (64)	20·0 (68)	23·8 (75)	10·5 (51)	94	—	,, ,,	
304	19 ,,	12.30 p.m	·00	·05	21·1 (70)	12·2 (54)	23·8 (75)	10·5 (51)	94	—	Effluent.	
305	19 ,,	12.45 ,,	·00	·05	21·1 (70)	12·2 (54)	23·8 (75)	10·5 (51)	94	—	,,	
306	24 ,,	11.30 a.m.	·00	·00	19·4 (67)	17·7 (64)	23·3 (74)	4·4 (40)	61	—	Settled sewage.	
307	24 ,,	12.45 p.m.	·00	·00	20·0 (68)	12·2 (54)	23·3 (74)	4·4 (40)	61	—	Effluent.	
308	25 ,,	11.45 a.m.	·00	·00	20·0 (68)	13·3 (56)	23·3 (74)	11·1 (52)	69		,,	
309	25 ,,	12.15 p.m.	·00	·00	18·8 (66)	12·7 (55)	23·3 (74)	11·1 (52)	69	—	,,	
310	27 ,,	10.45 a.m.	·00	·00	21·1 (70)	12·7 (55)	23·8 (75)	3·8 (39)	68	—	,,	
310a	2 July	12 noon	·10	·64	16·1 (60)	17·7 (64)	22·2 (72)	13·3 (56)	98	—	Crude sewage.	*Mean daily maximum temperature, 25·6° C(78·1°) F. Mean daily minimum temperature, 9·5° C (49·1°) F. Mean daily rainfall, ·06 in. Mean daily humidity, 71·2.
311	2 ,,	12.45 p.m.	·10	·64	16·1 (61)	16·1 (61)	22·2 (72)	13·3 (56)	98	—	Street washings.	
312	2 ,,	1 ,,	·10	·64	16·1 (61)	12·7 (55)	22·2 (72)	13·3 (56)	98	—	Effluent.	
313	3 ,,	11 a.m.	·64	·00	20·0 (68)	12·7 (55)	22·7 (73)	9·4 (49)	61	—	,,	*For the period 19th June to 24th July, 1901.
314	3 ,,	11.45 ,,	·64	·00	21·1 (70)	15·5 (60)	22·7 (73)	9·4 (49)	61	—	Street washings.	
314a	4 ,,	11.10 ,,	·00	·00	22·7 (73)	12·7 (55)	27·2 (81)	12·7 (55)	74	—	Effluent.	
314b	4 ,,	11.30 ,,	·00	·00	22·2 (72)	13·3 (56)	27·2 (81)	12·7 (55)	74	—	,,	
314c	4 ,,	11.45 ,,	·00	·00	22·2 (72)	12·7 (55)	27·2 (81)	12·7 (55)	74	—	,,	
314d	5 ,,	10.30 ,,	·00	·00	23·3 (74)	12·7 (55)	22·7 (73)	13·3 (56)	65	—	,,	
314e	5 ,,	11 ,,	·00	·00	23·8 (75)	13·3 (56)	22·7 (73)	13·3 (56)	65	—	,,	
314f	5 ,,	11.25 ,,	·00	·00	24·4 (76)	12·7 (55)	22·7 (73)	13·3 (56)	65	—	,,	
314g	8 ,,	11.5 ,,	·00	·00	20·0 (68)	18·8 (66)	24·4 (76)	9·4 (49)	66	—	Crude sewage.	
315	8 ,,	11.30 ,,	·00	·00	19·4 (67)	20·0 (68)	24·4 (76)	9·4 (49)	66	5	River water.	
316†	8 ,,	12 noon	·00	·00	20·0 (68)	20·0 (68)	24·4 (76)	9·4 (49)	66	3	River water and effluent	†A sample of red worms, marked No. 316a, taken from river below effluent outlet was sent to Professor Boyce.

ALDERSHOT CAMP FARM—Domestic Sewage—*continued.*

Number of Sample.	Date of drawing Sample.	Time of day.	Rainfall day previous to drawing Sample.	Rainfall day of drawing Sample.	Air Temperature time of drawing Sample.		Temperature of Sample.		Maximum Temperature during the 24 hours.		Minimum Temperature during the 24 hours.		Humidity (9 a.m.)	Dissolved Oxygen in Sample.	Brief description of Sample.	REMARKS.
	1901:		Inches.	Inches.	°C.	°F.	°C.	°F.	°C.	°F.	°C.	°F.				
314h	8 July	1 p.m.	·00	·00	21·1	(70)	12·7	(55)	24·4	(76)	9·4	(49)	66	5	Effluent.	
317	9 ,,	11 a.m.	·00	·00	20·0	(68)	13·8	(57)	27·7	(82)	7·2	(45)	67	—	,,	
317a	9 ,,	11.45 ,,	·00	·00	21·1	(70)	13·8	(57)	27·7	(82)	7·2	(45)	67	—	,,	
318a	10 ,,	10 30 ,,	·00	·00	24·4	(76)	14·4	(58)	27·7	(82)	8·3	(47)	66	—	,,	
318	10 ,,	10.49 ,,	·00	·00	24·4	(76)	14·4	(58)	27·7	(82)	8·3	(47)	66	—	,,	
318b	11 ,,	11.5 ,,	·00	·00	26·6	(80)	20·0	(68)	31·1	(87)	8·8	(48)	68	—	Crude sewage.	
318c	11 ,,	11.30 ,,	·00	·00	27·2	(81)	14·4	(58)	31·1	(87)	8·8	(48)	68	—	Effluent.	
318d	11 ,,	11.45 ,,	·00	·00	27·2	(81)	14·4	(58)	31·1	(87)	8·8	(48)	68	—	,,	
318e	12 ,,	10.55 ,,	·00	·15	28·3	(83)	15·0	(59)	28·8	(84)	13·8	(57)	72	—	,,	
318f	12 ,,	11.25 ,,	·00	·15	28·8	(84)	15·0	(59)	28·8	(84)	13·8	(57)	72	—	,,	
319a	15 ,,	10.30 ,,	·00	·00	21·1	(70)	15·0	(59)	23·8	(75)	6·6	(44)	73	—	,,	
319	15 ,,	10.15 ,,	·00	·00	21·6	(71)	15·0	(59)	23·8	(75)	6·6	(44)	73	—	,,	
319b	16 ,,	10.35 ,,	·00	·00	26·6	(80)	14·4	(58)	27·7	(82)	5·5	(42)	64	—	Crude sewage.	
319c	16 ,,	11.30 ,,	·00	·00	27·2	(81)	15·0	(59)	27·7	(82)	5·5	(42)	64	—	Effluent.	
320	17 ,,	10.45 ,,	·00	·00	26·6	(80)	25·5	(78)	31·1	(87)	5·5	(42)	63	—	Sewage from carrier.	
320a	17 ,,	11.45 ,,	·00	·00	27·2	(81)	15·0	(59)	31·1	(87)	5·5	(42)	63	—	Effluent.	
321	17 ,,	12.30 p.m.	·00	·00	27·2	(81)	15·0	(59)	31·1	(87)	5·5	(42)	63	—	,,	
322a	18 ,,	11.15 a.m.	·00	·00	31·1	(87)	15·0	(59)	32·7	(91)	9·4	(49)	69	—	,,	
322	18 ,,	11.35 ,,	·00	·00	29·4	(85)	15·0	(59)	32·7	(91)	9·4	(49)	69	—	,,	
322b	19 ,,	12 (noon)	·00	·00	32·2	(90)	15·0	(59)	33·3	(92)	10·5	(51)	60	—	,,	
322c	19 ,,	12.15 p.m.	·00	·00	32·2	(90)	15·0	(59)	33·3	(92)	10·5	(51)	60	—	,,	
323	22 ,,	11 a.m.	·00	·03	20·0	(68)	15·0	(59)	22·7	(73)	10·5	(51)	60	—	,,	

323a	22 ,,	11.30 ,,	·00	·03	20·5	(69)	20·0	(68)	22·7	(73)	10·5	(51)	60	—	Crude sewage.	
323b	22 ,,	4.30 p.m.	·00	·03	20·0	(68)	15·0	(59)	22·7	(73)	10·5	(51)	60	—	Effluent.	
324a	23 ,,	11 a.m.	·03	·20	18·3	(65)	15·0	(59)	21·6	(71)	11·1	(52)	90	—	,,	
324	23 ,,	11.15 ,,	·03	·20	18·8	(66)	15·0	(59)	21·6	(71)	11·1	(52)	90	—	,,	
325a	24 ,,	9.45 ,,	·20	·10	18·8	(66)	20·0	(68)	—		—		95	—	Crude sewage.	
325	24 ,,	10 ,,	·20	·10	18·8	(66)	16·1	(61)	—		—		95	—	Effluent.	
326	24 ,,	10.35 ,	·20	·10	18·8	(66)	16·1	(61)	—		—		95	—	River water.	*A sample of supernatant mud from river surface below effluent outlet, marked No. 328, was sent to Mr. McGowan.
327*	24 ,,	11 ,,	·20	·10	18·8	(66)	16·1	(61)	—		—		95	—	River water and effluent	
389	14 October	12.15 p.m.	·00	·00	13·8	(57)	13·8	(57)	15·0	(59)	7·7	(46)	—	—	Crude sewage.	
390	14 ,,	12.30 ,,	·00	·00	12·2	(54)	12·2	(54)	15·0	(59)	7·7	(46)	—	—	General effluent.†	†By "general" effluent is meant a mixture of two or more finally-treated effluents on leaving the farm.
391	14 ,,	1 p.m.	·00	·00	13·8	(57)	12·2	(54)	15·0	(59)	7·7	(46)	—	—	Effluent	
392	14 ,,	1.30 ,,	·00	·00	13·3	(56)	11·6	(53)	15·0	(59)	7·7	(46)	—	—	,,	
393	15 ,,	10.45 a.m.	·00	·08	14·4	(58)	13·3	(56)	15·5	(60)	2·7	(37)	—	—	Crude sewage.	
394	15 ,,	11.30 ,,	·00	·08	15·0	(59)	12·7	(55)	15·5	(60)	2·7	(37)	—	—	Effluent.	
395	15 ,,	12 noon	·00	·08	13·8	(57)	12·7	(55)	15·5	(60)	2·7	(37)	—	—	,,	
396	15 ,,	11.10 a.m.	·00	·08	14·4	(58)	12·2	(54)	15·5	(60)	2·7	(37)	—	—	General effluent.	*Mean daily maximum temperature, 15.3 ° C. (59·6° F.) Mean daily minimum temperature, 7·7° C. (46° F.) Mean daily rainfall, ·266 ins.
397	16 ,,	10.30 ,,	·08	·55	11·1	(52)	13·3	(56)	15·5	(60)	7·2	(45)	—	—	Crude sewage.	
398	16 ,,	11 ,,	·08	·55	11·6	(53)	12·2	(54)	15·5	(60)	7·2	(45)	—	—	General effluent.	
399	16 ,,	11.30 ,,	·08	·55	11·1	(52)	12·2	(54)	15·5	(60)	7·2	(45)	—	—	Effluent.	*For the period 13th October to 18th October 1901.
400	16 ,,	12 noon	·08	·55	11·1	(52)	12·2	(54)	15·5	(60)	7·2	(45)	—	—	,,	
401	17 ,,	10.15 a.m.	·55	·05	11·1	(52)	13·3	(56)	16·1	(61)	9·4	(49)	—	—	Settled sewage.	
402	17 ,,	10.40 ,,	·55	·05	11·1	(52)	11·6	(53)	16·1	(61)	9·4	(49)	—	—	General effluent.	
403	17 ,,	11.5 ,,	·55	·05	10·5	(51)	11·6	(53)	16·1	(61)	9·4	(49)	—	—	Effluent.	
404	17 ,,	11.20 ,,	·55	·05	10·5	(51)	11·1	(52)	16·1	(61)	9·4	(49)	—	—	,,	
405	18 ,,	10 ,,	·05	·65	12·2	(54)	13·3	(56)	14·4	(58)	11·6	(53)	—	—	Settled sewage.	
406	18 ,,	10.30 ,,	·05	·65	12·2	(54)	12·2	(54)	14·4	(58)	11·6	(53)	—	—	Effluent.	
407	18 ,,	10.50 ,,	·05	·65	12·2	(54)	12·2	(54)	14·4	(58)	11·6	(53)	—	—	General effluent.	
408	18 ,,	11 20 ,,	·05	·65	12·2	(54)	11·6	(53)	14·4	(58)	11·6	(53)	—	—	Effluent.	

ALDERSHOT CAMP SEWAGE FARM.

(Domestic Sewage.)

EFFLUENTS.

Number of Sample.	Number of times treated.	Area of plot or plots sewaged.	Period sewaged previously to drawing Sample.	Nature of crops grown on plots.	Remarks.
		Acres.	Days.		
49	Once	5·42	3*	Arable, fallow - -	Unchalked land.
51	,,	9·58 3·21	8*	Ryegrass - - -	,, ,, Very poor crop, laid down two years.
52	,,	4·9	3*	,, - - -	Unchalked land. Crop in good condition.
53	,,	—	—	—	General effluent.
55	,,	9·58 3·21	3*	Ryegrass - - -	Unchalked land.
56	,,	—	—	—	General effluent.
82	,,	3·0	6†	Young ryegrass - -	Chalked land. Young ryegrass only just up.
83	,,	3·0	7†	,, ,, - -	Chalked land. Young ryegrass only just up.
84	,,	3·0	8†	,, ,, - -	Chalked land. Young ryegrass only just up.
85	,,	3·0	9†	,, ,, - -	Chalked land. Young ryegrass only just up.
87	,,	3·0	14†	,, ,, - -	Chalked land. Young ryegrass only just up.
88	,,	3·0	15†	,, ,, - -	Chalked land. Young ryegrass only just up.
89	,,	3·0	—	—	General effluent.
90	,,	5·08	4‡	Ryegrass - - -	Chalked land.
246	,,	40·0	Various periods	Rye and arable - -	,, ,, General effluent.
247	,,	3·21	14*	Ryegrass - - -	Unchalked land.
304	,,	5·80	3*	,,	
305	,,	10·0	3*	,,	
307	,,	1·0	7*	,, (cut).	
308	,,	7.0	7*	,,	
309	,,	1·0	8*	,, (cut).	
310	,,	—	—	—	General effluent.
312	,,	1·50	15*	Ryegrass (cut).	
313	,,	1·50	16*	,, ,,	
314a	,,	1·50	17*	,, ,,	
314b	,,	7·0	3*	,,	
314c	,,	3·0	2*	,,	
314d	,,	1·50	18*	,, (cut).	
314e	,,	3·0	3*	,,	
314f	,,	3·0	7*	,,	
314h	,,	1·50	21*	,, (cut).	
317	,,	1·50	22*	,, ,,	
317a	,,	—	—	—	General effluent.
318a	,,	—	—	—	,, ,,
318	,,	1·75	23*	Ryegrass (cut).	
318c	,,	—	—	—	,, ,,
318d	,,	1·75	24*	Ryegrass (cut).	
318e	,,	—	—	—	,, ,,
318f	,,	1·75	25*	Ryegrass (cut).	
319a	,,	—	—	—	,, ,,
319	,,	3·21	5*	Ryegrass.	
319c	,,	5·08	6*	,, (cut).	
320a	,,	—	—	—	,,
321	,,	1·75	2*	Ryegrass (cut).	
322a	,,	—	—	—	,, ,,
322	,,	2·0	3*	Ryegrass (cut).	
322b	,,	—	—	—	,, ,,
322c	,,	3·25	7*	Ryegrass.	
323	,,	2·0	7*	Ryegrass (cut).	
323b	,,	—	—	—	,, ,,
324a	,,	—	—	—	,,
324	,,	2·0	8*	Ryegrass (cut).	
325	,,	2·0	9*	,, ,,	
390	,,	—	—	—	,, ,,
391	,,	3·0	7*	,, - - -	Final ,,
392	,,	4·0	6*	,, - - -	,,
394	,,	3·0	8*	,, - - -	,, ,,
395	,,	4·0	7*	,, - - -	,, ,,
396	,,	—	—	—	General ,,
398	,,	—	—	—	,, ,,
399	,,	3·0	9*	,, - - -	Final ,,
400	,,	4·0	8*	,, - - -	,, ,,
402	,,	—	—		General ,,
403	,,	3·0	10*	,, - -	Final ,,
404	,,	4·0	9*	,, - - -	,, ,,
406	,,	3·0	11*	,, - - -	,, ,,
407	,,	—	—	—	General ,,
408	,,	4·0	10*	,, - -	Final ,,

* Plot sewaged continuously day and night. † Land sewaged for 12 hours by day only. ‡ Sewaged night and day

ALDERSHOT CAMP FARM.

(Domestic Sewage.)

* Corresponding Effluents.

From Old Land.	From New Land A.	From New Land B.	Remarks.
Sample Nos. 48 and 49. ,, ,, 50 and 51. ,, ,, 54 and 55. ,, ,, 302 and 304. ,, ,, 303 and 305. ,, ,, 314c and 314e.	Sample Nos. 81 and 82. ,, ,, 86 and 87.	Sample Nos. 306 and 307. ,, ,, 314G and 314H.	**i.e.*, effluents corresponding to crude or screened and settled sewage in each case. That is to say, that the effluent is taken some time after the sewage sample, to show as far as possible the degree of purification effected on that particular sewage.

* Comparative Samples, or Samples taken from the same Plots of Land.

† Old Land.	‡ New Land B.	§ New Land A.	Remarks.
Nos. (51) (55) (314c) (314e)	Nos.	Nos. (321) (322) (323) (324) (325)	* By "comparative" samples is meant samples drawn from the same areas of land, and the effluents in brackets are comparable with each so far as the area of land sewaged is concerned.
	(307) (309)	82 83 84	† By "old" land effluents is meant those effluents from the old portion of the farm as distinct from the "new."
(391) (394) (399) (403) (406)	(312) (313) (314a) (314d) (314h) (317)	85 87 88 (392) (395) (400)	‡ New land "A" (coloured pink on small plan accompanying Mr. Kershaw's report), was brought into operation in May, 1900. § New land "B" (coloured green on small plan) was brought into operation in June, 1901.
	(318) (318d) (318f)	(404) (408) 461 463 465	

Sewage Samples.

Number of Sample.	Nature of Sewage.	Source.	Time taken.	Remarks.
46	Crude sewage	Wellington Lines Tanks	11 a.m. -	Very strong, taken before being screened or entering tanks.
50	Screened and settled sewage	Stanhope ,, ,, -	11 a.m. -	Very strong, taken after being screened and settled.
54	,, ,,	,, ,, ,, -	1 p.m. -	,, ,, ,, ,,
81	,, ,, -	Marlborough ,, ,, -	11.45 a.m.	Very strong, taken after being screened and settled, slightly alkaline.
86	,, ,, -	,, ,, ,, -	12.45 p.m.	Soapy sewage, taken after being screened and settled.
245	,, ,, -	,, ,, ,, -	2 p.m. -	Fairly strong ,, ,, ,,
302	,, ,, -	Stanhope ,, ,, -	11.5 a.m. -	,, ,, ,, ,,
303	,, ,, -	Marlborough ,, ,, -	11.30 a.m.	Very strong ,, ,, ,,
306	,, ,, -	,, ,, ,, -	11.30 a.m.	Very strong, taken after being screened and settled, septic-looking
314g	Crude sewage	,, ,, ,, -	11.15 a.m.	Very strong, taken before being screened and settled.
318b	,, ,, -	,, ,, ,, -	10.49 a.m.	,, ,, ,, ,,
319b	,, ,, -	,, ,, ,, -	10.35 a.m.	Fairly strong ,, ,, ,,
320	Screened and settled sewage	,, ,, ,, -	10.45 a.m.	‡Not very strong, taken after being screened and settled.
323a	Crude sewage	,, ,, ,, -	11.30 a.m.	,, ,, before ,, ,,
325a	,, ,, -	,, ,, ,, -	9.45 a.m. -	,, ,, ,, ,, ,,
389	,, ,, -	Stanhope ,, ,, -	12.15 p.m.	Strong, taken before passing through settling tank.
393	,, ,, -	,, ,, ,, -	10.45 a.m.	Apparently stronger than 389, probably owing to time of day.
397	,, ,, -	,, ,, ,, -	10.30 a.m.	Apparently weaker than usual owing to rainfall.
401	Screened and settled sewage	,, ,, ,, -	10.15 a.m.	A strong sample, owing to very heavy rain scouring out the sewers.
405	,, ,, -	,, ,, ,, -	10.15 a.m.	Fairly strong.

‡ Taken from the carrier just before going on to the land.

ADDENDUM E.—(*continued*)—Mr. KERSHAW'S Abridged Notes to Accompany Bacteriological Report.

ADDITIONAL NOTES ON DIFFERENT SAMPLES.

ALDERSHOT CAMP FARM.

(Domestic Sewage.)

WINTER VISIT.

Sample No. 50.—Screened and settled sewage from Stanhope Lines, one mile distant, and having passed through a bar screen with ¾-inch spaces and settling tank.

Sample No. 52.—This effluent represents an average sample of the farm during wet weather.

Sample No. 53.—General effluent contained some sewage weed. During wet weather the sewage in consequence of the increased flow sometimes reaches portions of the land not usually irrigated, and should there be any rat or mole holes, reaches the drains imperfectly purified. In addition any accumulation of sewage weed or sediment in the drain during a dry period is washed out in times of rainfall.

Sample No. 56.—General effluent very dirty yellow colour—turbid—a good deal of it being caused no doubt by some of it having come off the worst parts of the farm ; *i.e.*, the parts not drained or levelled.

Sample No. 57.—River water taken 30 yards above junction of effluent outlet—a fairly clear sample, river about normal height (about 4,000,000 gallons per 24 hours). The river appeared to be in a fairly satisfactory state.

Sample No. 58.—River water and effluent taken 30 yards below effluent outlet ; the effluent entering the river channel at right angles, appeared to be thoroughly mixed with river water.

Sample No. 59.—River water and effluent, taken 170 yds. below effluent outlet. This sample could not be taken any lower down the river owing to another brook joining the river at that point. Some cattle had apparently been in the stream some time previously to drawing the sample.

Sample No. 60.—Subsoil water drawn from a pump well near the farm, 8 ft. deep (no chance of contamination from the farm) ; 3 ft. 6 in. of water in the well at time of drawing sample—very clear and sparkling appearance. This well varies in depth according to the amount of rainfall. In July, 1901, the water was 1 ft. 6 in. deep.

SPRING VISIT.

Sample No. 82.—Effluent from new land (3 acres) sewaged 6 days, by day only for 12 hours (*i.e.*, 6 a.m. to 6 p.m.). Effluent smelt strongly of sewage and was of a deep orange colour. The ryegrass was newly sown, and was not up sufficiently to affect the purification appreciably. The sewage was flowing on at about the rate of 20,000 gallons per 24 hours.

The surface of the soil was not yet consolidated, being left 2 inches to 3 inches higher than the other land to allow of settlement.

In preparing the land a 4-horse deep plough was employed, this leaving the soil loose immediately beneath the surface and causing the sewage in some parts to run direct to the drains.

Sample No. 83.—Some large holes letting the sewage direct to the drains. Orange-coloured effluent.

Sample No. 84. Holes in land filled up and rammed. Orange-coloured effluent.

Sample No. 85.—Yellow coloured effluent, and slight smell.

Sample No. 87.—Some holes in land started again. Land to be thoroughly rolled once the sewage has been taken off it to consolidate it.

Waterman walking about stirs up the sediment. Effluent orange coloured.

Sample No. 88.—Holes stopped up. Effluent not quite so deep an orange colour.

Sample No. 89.—General effluent from old land—yellow coloured—slight sediment. This would include the new land final effluent.

Sample No. 90.—Effluent from old land, 5·08 acres ryegrass, sewaged for 4 days. Fairly clear, slight smell

Sample No. 245.—Screened and settled sewage from Marlborough Lines. New tanks now in use and better sedimentation obtained thereby. Sewage strong. Sewage is strongest about 10 a.m. and 3 p.m. This sample was drawn the day following heavy rainfall.

Sample No. 246.—General effluent from about 40 acres of old land, slight sewage smell, yellowish colour, some sewage fungus. Heavy rainfall appears to disturb the soil for some time afterwards, some of the surface soil being apt to wash off in heavy storms. This general effluent had no effluent water from the new land running into it.

Sample No. 247.—Effluent from old land ryegrass, 3·21 acres, sewaged 14 days, fairly clear and no smell.

Note.—Effluents subsequent to No. 247 were all drawn from land that had been chalked.

---

* In a few instances samples referred to in this Addendum are not accompanied by any bacteriological records. These samples were extra ones, collected by Mr. Kershaw for chemical analysis.

† Does land, as is the case with water filters, only arrive at its full purifying power after a certain number of days ? Up to a certain point that is ? As regards this point the South Norwood, Leicester, and Beddington experiments should be instructive, in view of their having been carried on for a continuous period on practically the same plots.

SUMMER VISIT.

Sample No. 304.—Effluent from old land, 5·80 acres, ryegrass, sewaged 3 days ; only fairly clear, very slight smell.

Sample No. 305.—Effluent from old land, 10 acres ryegrass (*i.e.*, 11.55 plot), sewaged 3 days ; yellowish colour, decided smell, some sewage fungus.

Sample No. 307.—Effluent from new land, hay crop only just gathered off ground. Surface cut about by wagons and carts. A mere dribble of effluent running, opalescent colour.

Sample No. 308.—Effluent from old land, yellowish colour, some sewage fungus.

Sample No. 309.—Effluent from new land ; deep yellow, opalescent colour. Land not set very well, and cut up by carts during hay-time, etc. Moles worked during the time that the field was dry.

Sample No. 310.—General effluent, yellow colour, some finely divided sewage weed, strong sewage smell.

Sample No. 311.—Street washings and roof water taken from surface water ditch, after two days' heavy rainfall, *i.e.*, probably as pure as one could expect to obtain it. At the time of drawing sample this surface water ditch was flowing at about the rate of 10,000,000 gallons per 24 hours ; sample a turbid brown colour.

Sample No. 312.—Effluent from new land. Sample drawn during very heavy rainfall (·64 inches) ; some sewage was escaping direct over the surface of the land to the pick-up carrier at foot of plot and thence to effluent chamber. Some solids were washed on to the land ; in consequence partly of the sewage being put upon the land in larger quantities than usual, to soak the land, this in combination with the rainfall producing the overflow. The worst sample drawn, being practically weak sewage.

Sample No. 313.—Effluent from new land, yellow colour, land only just recovering from the heavy rain.

Sample No. 314.—Street washings and roof water after 3 days' rain, turbid and apparently worse than the previous sample of street water, probably owing to a slight escape of sewage from the farm.

Sample No. 314A.—Effluent from new land. No visible short cuts of sewage to drains. Effluent still very yellow in colour ; the ryegrass growing very slowly in consequence of drought, but assisted by late rains.

Sample No. 314B.—Effluent from old land ; some suspended matter in effluent ; not a very clear sample.

Sample No. 314C.—Effluent from old land. Not a very clear sample, and a good deal of sediment.

Sample No. 314D.—Effluent from new land, yellow colour ; land apparently in fair working order.

Sample No. 314E.—Effluent from old land, fairly clear.

Sample No. 314F.—Effluent from old land, a good deal of suspended matter.

Sample No. 314H.—Effluent from new land, yellow colour.

Sample No. 315.—River water above effluent outfall, cloudy blue colour, 5 c.c.'s dissolved oxygen A good deal of froth and scum coming down the stream owing to rainfall.

Sample No. 316.—River water 20 yards below effluent outfall, dissolved oxygen 3 c.c. Cloudy blue colour, some fermentation going on in the stream.

Sample No. 317.—Effluent from new land, yellow colour, slight seaweed smell.

Sample No. 317A.—General effluent from old and new land ; a clear-looking sample, very little suspended matter, slight seaweed smell. This represents as far as could be judged a fair sample of a "general" or "combined" effluent in dry weather.

Sample No. 318.—Effluent from new land, yellow colour, strong seaweed smell.

Sample No. 318A.—General effluent from old and new land, about same in appearance as No. 317A, but clearer if anything, slight seaweed smell.

Sample No. 318C.—General effluent, fairly clear, similar to No. 318A in appearance.

Sample No. 318D.—Effluent from new land, yellow colour ; a larger flow of effluent running, similar in appearance to No. 318.

Sample No. 318E.—General effluent from old and new land, similar to No. 318D in conditions and appearance, but apparently more suspended matter. Perhaps due to increased flow and therefore scouring action.

Sample No. 318F.—Effluent from new land, similar in appearance to No. 318E, but slightly less suspended matter.

Sample No. 319.—Effluent from old land ; a good deal of suspended matter.*

Sample No. 319A.—General effluent from old and new land ; a fairly clear sample, green algae showing in effluent chamber.

Sample No. 319C.—Effluent from old land ; a very fairly clear sample, ryegrass just starting to grow.

Sample No. 320.—Screened and settled sewage taken from the carrier just before going on to the new land ; rather weak.

Sample No. 320A.—General effluent from old and new land, a farly clear sample.

Sample No. 321.—Effluent from new land, B Plot, sewaged for 2 days, day and night continuously ; very little effluent running owing to drought ; deep yellow colour.

Sample No. 322.—Effluent from new land B, sewaged continuously for 3 days ; effluent a deep yellow colour; still very little running, probably due in some measure to the sewage being on a slightly increased area. A large amount of sediment in effluent.

Sample No. 322A.—General effluent from old and old new land, some little sediment coming down, slight smell.

Sample No. 322B.—General effluent from old and old new land, similar to No. 322A in colour, but more sediment.

---

* *Note.*—During very lengthy periods of drought, the amount of effluent coming away from the farm is often diminished by as much as one-half. When a field or plot is left dry for some days and then sewaged, a good deal of matter washes from the drains at first.

Sample No. 322c.—Effluent from old land ; a fairly clear sample, no perceptible smell.

Sample No. 323.—Effluent from new land B, sewaged day and night continuously ; very little effluent running, and much red suspended matter ; a good deal of sediment was stirred up owing to having to collect sample in very small quantities.

Sample No. 323B.—General effluent from old land and new land ; a good deal of suspended matter, owing no doubt to slight rainfall ; a slight sewage smell.

Sample No. 324.—Effluent from new land B.

Note.—A slight amount of only surface-treated sewage had entered effluent at bottom of plot ; effluent a frothy, dirty colour in consequence.

Sample No. 324A.—General effluent from old land and new land B. only fairly clear, in all probability affected by bad effluent from new land B.

Sample No. 325.—Effluent from new land B (raining heavily during drawing of sample), a little surface treated sewage getting in.

Sample No. 326.—River water taken 30 yards above effluent outlet; river rather high (about at the rate of 10,000,000 gallons per 24 hours) ; a turbid sample drawn during rain.

Sample No. 327.—River water taken 30 yards below effluent outlet; no perceptible difference between the two samples, No. 327 if anything clearer than No. 326.

Sample No. 390.—General Effluent : Some suspended matter, yellowish colour ; hardly such a good sample as usual.

Sample No. 391.—Final Effluent : A clear sample.

Sample No. 392.—Final Effluent : Very little effluent running, top end only of plot being sewaged ; slight sewage smell.

Sample No. 394.—Final Effluent : From same source as 391, clear.

Sample No. 395.—Final Effluent : From same source as 392, yellow colour ; a little more effluent running.

Sample No. 396.—General Effluent : Slightly less suspended matter than in No. 390.

Sample No. 398.—General Effluent : Some sediment, rather dilute, owing to rain (·20 inch) ; rain also probably caused more sediment.

Sample No. 399.—Final Effluent : Same source as 394 ; some sediment, due to rainfall, otherwise clear.

Sample No. 400.—Final Effluent : Same source as 395 ; yellow colour, a good deal of sediment ; a fair amount of effluent running.

Sample No. 402.—General Effluent : Fairly clear ; very slight sewage smell, after heavy rain.

Sample No. 403.—Final Effluent : Same source as 399, clear, no smell.

Sample No. 404.—Final Effluent : Same source as 400 ; yellow colour. After ·55-inch rainfall sewage smell.

Sample No. 406.—Final Effluent : Same source as 403 ; clear, no smell ; ·30 inch fell during drawing of samples.

Sample No. 407.—General Effluent : Fairly clear ; taken during heavy rain.

Sample No. 408.—Final Effluent : Same source as 404 ; a fair amount of effluent running and less yellow than previously ; taken during heavy rain.

Sample No. 461.—Final Effluent : This effluent was undoubtedly affected by the heavy rainfall, and was dilute.

Sample No. 463.—Final Effluent : This sample contained some red flocculent matter.

Sample No. 465. Final Effluent : Some red suspended matter, otherwise a very clear sample.

24 hours sewage samples, Nos. 460, 462, and 464.—These samples were taken from the screened and settled sewage on leaving the tanks, that being the condition in which it is applied to the land.

SECTION II.

ALTRINCHAM SEWAGE FARM.

1. Situation of farm.—Bordering on Carrington Moss, about 2 miles from Altrincham.

2. Total acreage of farm.—75·5 acres.

3. Total irrigable area.—35 acres.

4. Average area irrigated at one time.—17·5 acres.

5. Population draining to farm.—18,000.

6. Population per acre irrigated.—514.

7. Gallons of sewage per head per day.—44·4.

8. Dry-weather flow of sewage per 24 hours.—800,000 gallons.

9. Gallons of sewage (exclusive of storm water) treated per acre per 24 hours.—46,000 = $(\frac{800000}{17 \cdot 5})$.

10. Gallons of sewage treated per acre per 24 hours, on the assumption that each acre of irrigable area is under sewage all the time. (This for purposes of comparison) = $(\frac{800000}{35})$ = 23,000 gallons.

11. Characters of the sewage.—Domestic.

12. Method of treatment.—Settling tanks and land filtration.

13. General characters of the soil and subsoil.—Peaty (to some extent) soil, lying upon sand and gravel.

14. Separate or combined sewerage system.—Combined.

15. The final effluent is discharged into.—Sinderland Brook.

16. Number of years farm in operation before 1900.—30 years.

A full description of Altrincham Sewage Farm will be found in Mr. Kershaw's Report (Part IV. Engineering and Practical Report). It is therefore necessary merely to allude here to a few of the more important points mentioned in his Report.

The sewage is domestic. The town of Altrincham is chiefly on the water-closet system, but there are also a number of privies, the contents of which are not dealt with on the farm. The soil varies in character, but may be described as a partially peaty soil, resting upon sand and gravel. The sewerage system is a combined one. A good deal of subsoil water enters the sewers, but on the farm itself but little reaches the under-drains. The main storm overflow works at less than twice the dry weather flow. The method of treatment is by settling in a tank and in lagoons and land filtration. The sludge is mixed with farmyard manure and dug or ploughed into the land. The irrigable area is under-drained, and it is worth noting that the peat removed during the draining operations was replaced by good soil. About one-third of the irrigable area is laid out in osier beds. The remainder, with the exception of a small meadow which is sewaged only during heavy storms is arable land, and the chief crops are mangolds and cabbages. The effluents are discharged into Sinderland brook, which borders the farm. The ratio of effluents to brook water is about 1 to 3. Quoting from Mr. Kershaw's report :—" *The total area of the farm is at present* (1900) 75·5 *acres,* 35 *acres of which are irrigated. Taking the irrigable area* (*viz.*, 35 *acres*) *as dealing with* 800,000 *gallons of sewage per* 24 *hours and a population of* 18,000, *this comes to* 514·4 *persons per acre, or about* 23,000 *gallons per acre ; and since in dry weather about one half of the irrigable area is sewaged at one time, this gives about* 46,000 *gallons of sewage treated per acre per* 24 *hours.*"

The following is a summary of the several sections of the Report in so far as it relates to Altrincham Sewage Farm.

1. Tabular statement and summary of the chief bacteriological results.

2. Diagram 3 illustrating the results shown in Table 4 with comments thereon.

3. Results considered in relation to Mr. Kershaw's notes.

4. Results in relation to tests other than B. enteritidis sporogenes.

5. Results of the examination of additional samples of mixed effluent and brook water, subsoil water, and street "washings."

6. General conclusions.

Addendum A.—Comparative records as regards (1) the "gas" and (2) B. enteritidis sporogenes tests of samples obtained from Altrincham as well as other sewage farms.

Addendum B.—Comparative records as regards (1) the "gas"; (2) B. enteritidis sporogenes; (3) neutral red broth; and (4) litmus milk tests of samples obtained from Altrincham as well as other sewage farms.

Addendum C.—Mr. Kershaw's abridged notes to accompany bacteriological data.

1. Tabular statement and summary of the chief bacteriological results.

The following table (Table 4) shows as regards the total number of bacteria, B. coli, and spores of B. enteritidis sporogenes, the results of the bacteriological examination of the samples obtained from Altrincham Sewage Farm.

TABLE 4. Showing, as regards the total number of bacteria, B. coli, and spores of B. enteritidis sporogenes, the results of the bacteriological examination of samples of sewage and effluent obtained from Altrincham Sewage Farm.

Description of the Sample.	Total Number of bacteria per c.c.		Number of B. coli. (or closely allied forms) per c.c.	Number of Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in milk cultures) per c.c.	
	Gelatine at 20° C.	Agar at 37° C.			
1.	2.	3.	4.	5.	
64 Settled sewage - - - 10.15 a.m., 26th April 1900.	1,000,000	124,000	10,000 not 100,000 -	+ ·01, – ·001 c.c. At least 100 but less than 1,000.	
65 First effluent from lagoon - 11.30 a.m., 26th April 1900.	11,300,000	1,920,000	At least 100,000 -	- ditto - ditto.	
69 Ponded lagoon liquor - - 11.50 p.m., 30th April 1900.	22,200,000	290,000	At least 10,000 -	+ ·1, – ·01 c.c. At least 10 but less than 100.	
75 Settled sewage from tank - 11.30 a.m., 30th April 1900.	11,100,000	1,160,000	At least 100,000 -	+ ·01, – ·001 c.c. At least 100 but less than 1,000.	
249 Settled sewage - - - 10.45 a.m., 17th April 1901.	12,300,000	240,000	10,000 not 100,000 -	+ ·1, – ·01 c.c. At least 10 but less than 100	
264 Sewage - - - - Noon, 30th April 1901.	12,600,000	750,000	At least 100,000 -	+ ·01, – ·001 c.c. At least 100 but less than 1,000.	
265 Liquor from first lagoon - 12.30 p.m., 30th April 1901.	17,040,000	1,476,000	At least 10,000 -	- ditto - ditto.	
266 Liquor from second lagoon - 1 p.m., 30th April 1901.	9,440,000	1,632,000	- ditto - -	+ ·1, – ·01 c.c. At least 10 but less than 100.	
275 Liquor from last lagoon - 11.30 a.m., 8th May 1901.	27,400,000	6,540,000	At least 100,000 -	+ ·01, – ·001 c.c. At least 100 but less than 1,000.	
Averages - - -	13,820,000	1,570,222	[Ratio of cols. 2 to 3 = 8·8 : 1.]		
66 Final effluent - - - 12.15 p.m., 26th April 1900.	51,000	3,800	At least 100 - -	+ 10 c.c., – 1 c.c.	First Visit, April and May 1900.
70 Effluent ponded liquor from lagoon. 1.15 p.m., 30th April 1900.	920,000	14,100	1,000 not 10,000 -	+ 1, – 0·1 c.c. At least 1 but less than 10.	First Visit, April and May 1900.
72 General effluent - - - 11.50 a.m., 7th May 1900.	960,000	26,000	At least 1,000 -	- ditto - ditto.	First Visit, April and May 1900.
76 Effluent from osier beds - 1 p.m., 15th May 1900.	232,000	16,000	1,000 not 10,000 -	+ ·1 – ·01 c.c. At least 10 but less than 100.	First Visit, April and May 1900.
77 Final effluent - - - 11.50 a.m., 16th May 1900.	103,000	10,200	- ditto - -	- ditto - ditto.	First Visit, April and May 1900.
248 Final lagoon filtration effluent. 11.10, a.m. 16th April 1901.	1,240,000	13,000	- ditto - -	- ditto - ditto.	Second Visit, April and May 1901.
250 Final effluent - - - Noon, 17th April 1901.	848,000	6,900	At least 100 - -	- ditto - ditto.	Second Visit, April and May 1901.
251 Effluent from osier beds - 12.30 p.m., 17th April 1901.	137,000	2,000	100 not 1,000 - -	+ 1, – ·1 c.c. At least 1 but less than 10.	Second Visit, April and May 1901.
252 Effluent (final) - - - 11.10 a.m., 22nd April 1901.	53,000	930	At least 100 - -	- ditto - ditto.	Second Visit, April and May 1901.
253 Effluent from osier beds - 11.20 a.m., 22nd April 1901.	232,000	3,100	- ditto - -	- ditto - ditto.	Second Visit, April and May 1901.
254 Effluent from osier beds - 11.45 a.m., 22nd April 1901.	80,000	1,200	- ditto - -	- ditto - ditto.	Second Visit, April and May 1901.
255 Final lagoon filtration effluent. Noon, 22nd April 1901.	304,000	2,200	- ditto - -	- ditto ditto.	Second Visit, April and May 1901.
267 Final effluent from lagoon - 10.45 a.m., 1st May 1901.	166,000	2,600	100 not 1,000 - -	- ditto - ditto.	Second Visit, April and May 1901.
274 Final lagoon filtration effluent. 2.30 p.m., 7th May 1901.	74,000	2,800	At least 100 - -	- ditto - ditto.	Second Visit, April and May 1901.
276 Final effluent - - - 12.30 p.m., 8th May 1901.	51,000	4,300	- ditto - -	- ditto - ditto.	Second Visit, April and May 1901.
Averages - - -	363,400 [97% reduction]	7,275 [99% reduction]	[Ratio cols. 2 to 3 = 49·9 : 1		

The following is a brief summary of the results shown in Table 4 :

Sewage and Lagoon Liquor :—

The average results are as follows :—Total number of bacteria over ten million (gelatine at 20°C.), and more than one million but less than ten million (agar at 37°C.) respectively per c.c. B. coli and B. enteritidis sporogenes usually 100,000 and 100 respectively per c.c.

Effluents :—

Total number of bacteria (gelatine at 20°C.) *per c.c.* :—One sample contained over one million. Nine samples between 100,000 and one million. Five samples over 10,000, but less than 100,000, [Provisional standard, less than 100,000 per c.c.]

Total number of bacteria (agar at 37°C.) *per c.c.* :—Five samples contained more than 10,000, but less than 100,000. Nine samples between 1,000 and 10,000; and one sample less than 1,000. [Provisional standard, less than 10,000 per c.c.]

Number of B. coli (and closely allied forms) per c.c. :—Five samples contained 1,000 : ten samples 100 per c.c. [Provisional standard, less than 1,000 per c.c.]

Number of B. enteritidis sporogenes per c.c. :—One sample contained none in 1c.c. Ten samples 1 but less than 10. Four samples 10 but less than 100. [Provisional standard less than 10 per c.c.]

2. *Diagram* 3 *illustrating the results shown in Table* 4, *with comments thereon*

The results are shown in graphic form in Diagram 3. By referring to Diagram 3 it will be seen that certain horizontal lines are drawn indicating provisional standards (non-drinking water streams).

All samples which did not, according to these standards, fulfil the following requirements would be tentatively condemned :—

1. Total number of bacteria (gelatine at 20° C.). Less than 100,000
2. Total number of bacteria (agar at 37° C.). Less than 10,000 -
3. B. coli. Less than 1,000 - - - - - - -
4. B. enteritidis sporogenes. Less than 10 - - - - -

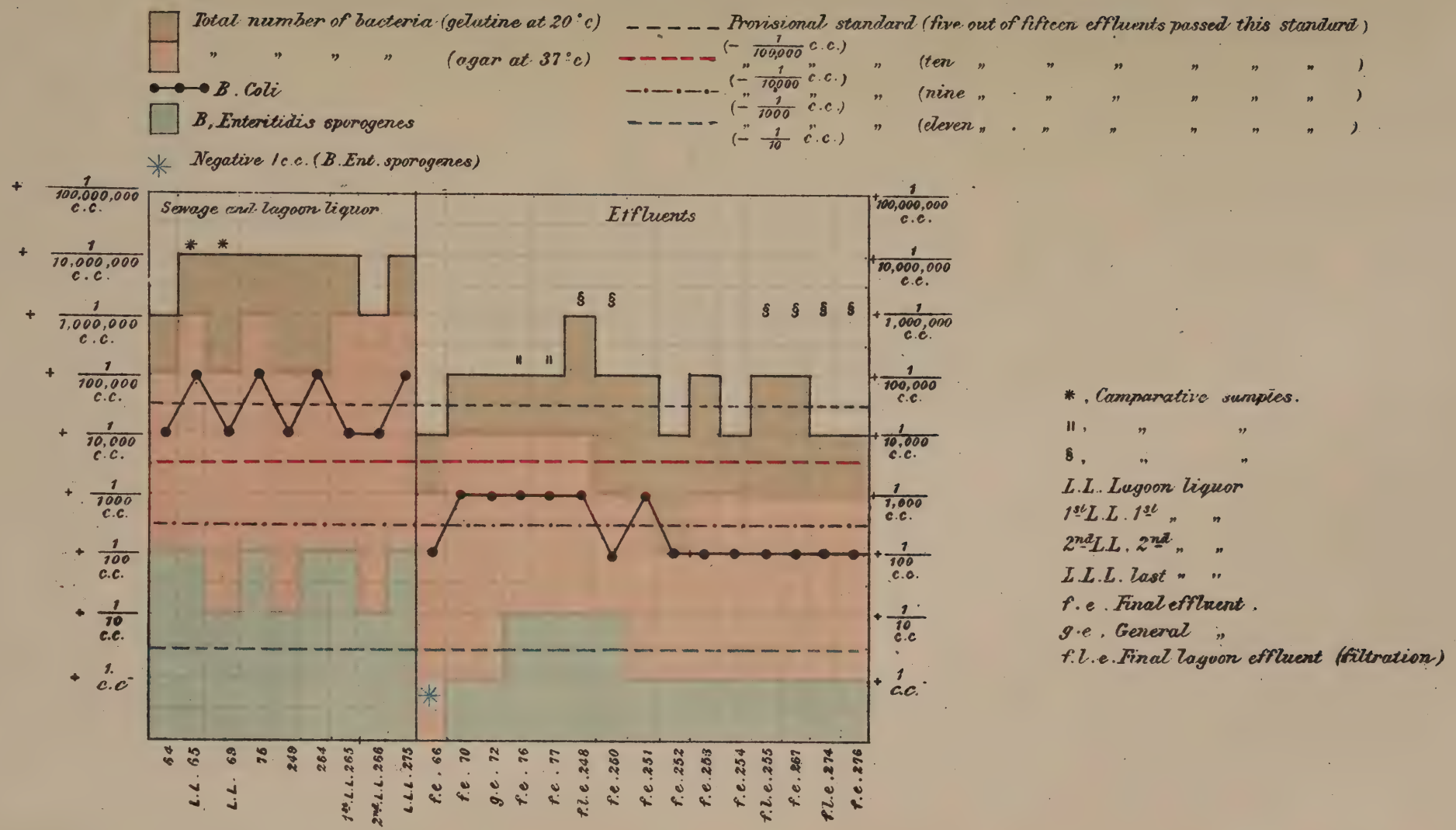
} Per c.c.

As regards (1) 5 out of 15 effluents proved satisfactory.
(2) 10 ,, ,, ,,
(3) 9 ,, ,, ,,
(4) 11 ,, ,, ,,

Speaking in general terms, it may be said that the majority of the effluents were satisfactory.

Taking the B. enteritidis sporogenes results as a ready means of gauging the degree of biological purification effected, it is to be noted that while the sewage and lagoon liquors contained from ten (3 out of 9 samples) to one hundred (6 out of 9 samples) spores of this anærobe per c.c. the effluents varied as follows :—Out of 15 samples, only four contained 10; and ten samples of effluents contained 1 but less than 10 spores of this anærobe in 1 c.c. One sample gave a negative result even with 1 c.c. The effluents then, judged by this test, were nearly always satisfactory. The sewage and lagoon liquors yielded, as regards this test, however, lower results than is perhaps usual. Commonly sewage yields results as follows;—From 100 to 1,000 spores of B. enteritidis sporogenes per c.c., but oftener 1,000 than 100; less frequently, as many as 10,000 or as few as 10.

sporogenes the results of the bacteriological examination of samples of sewage and effluents obtained from Altrincham Sewage farm.



3311. 9. 02.

Weller & Graham Ltd Litho. London.

*Results considered in relation to Mr. Kershaw's notes.**

It is important to study Mr. Kershaw's notes in relation to the use of lagoons as a means of "settling out the grosser impurities in the sewage before its final application on the land." This is an unusual arrangement, but, judging by the final results, the process may possibly be in certain cases useful. It was adopted, in the case of Altrincham Sewage Farm, owing to the insufficient capacity of the existing settling tank. In hot weather, however, it gave rise to a nuisance.

Samples 65, 69, 265, 266, 275, were all lagoon liquors, and they have been classed as sewages in the bacteriological tables. The last three are of interest because they represent the surface liquid in the first, second, and third lagoons. They (265, 266, and 275) did not differ from each other biologically to any conspicuous extent.

As regards the filtration effluents from the sewage impounded in lagoons, Mr. Kershaw collected three samples, viz., 248, 255, and 274. As regards 248, Mr. Kershaw states that it had a sewage smell, and it is worth noting that this sample yielded, on bacteriological analysis, unsatisfactory results. The other two samples, 255 and 274, were good effluents.

Sample 72 was a general effluent; all the remaining samples of effluent were final effluents.

Samples 76, 77, and 251 were effluents from the osier bed; 76 and 77 were rather less satisfactory than the average.

Occasion will be found later to refer further to Mr. Kershaw's report and notes, especially in relation to the samples of storm water and brook samples.

Results in relation to tests other than the B. enteritidis sporogenes test.

Up to the present, prominence has been given to the B. enteritidis sporogenes test, but it is necessary to supplement these notes with a brief reference to the bacteriological results in general.

The results as regards the average total number of bacteria in the sewage and effluents were as follows :

	Gelatine at 20° C. Microbes per c.c.	Agar at 37° C. Microbes per c.c.	Ratio.
Sewage - -	13,820,000	1,570,222	8·8 : 1
Effluents - -	363,400 (97 per cent. reduction)	7,275 (99 per cent. reduction)	49·9 : 1

These results indicate, in the effluents, a high percentage degree of purification, and the total number of bacteria remaining in the effluents, although large, is only slightly in excess of the standard (less than 100,000 microbes at 20° C.) and 7275 is below the standard for blood-heat bacteria. A striking feature of the results is that the ratio of microbes growing at blood-heat to total numbers was markedly altered by the land treatment. Thus, in the case of the sewage and lagoon liquors, for every blood-heat microbe there were about 9 of all sorts (gelatine at 20° C.); whereas as regards the effluents the ratio, instead of being as 1 to 9, was about 1 to 50.

The results in the case of B. coli were, on the whole, of a satisfactory nature. The sewage and lagoon liquors contained from 100,000 to 10,000 B. coli per c.c., while in the effluents, the number was much reduced, varying between 1,000 and 100 in 1 c.c., and the majority (9 out of 15) contained less than 1,000.

* Addendum C. page 49.

In the table and diagram illustrating Appendix III. (page 196) the results as regards he "gas" and B. enteritidis sporogenes tests are brought into comparison. Of 15 effluents 9 passed the former and 11 the latter test.

In the table and diagram illustrating Appendix IV. (page 203), the gas, B. enteritidis sporogenes, neutral red broth, and litmus milk tests are compared. In this comparative series of experiments, however, but few samples from Altrincham are included.

Indol test (indol in broth cultures 5 days at 37° C.):

Sewage	Samples 64, 65, 75	+ ·00001 c.c.
	Samples 69, 249, 265, 266, 275	+ ·0001 c.c.
Effluents	Samples 70, 76	+ ·0001 c.c.
	Samples 72, 77, 248, 250	+ ·001 c.c.
	Samples 66, 251, 252, 253, 255, 267, 274, 276	+ ·01 c.c.
	Samples 254	+ ·1 c.c.

The majority of the effluents were satisfactory as judged by this test.

Results of the bacterological examination of additional samples of storm water, river water, and subsoil water.

These results are shown in Table 5.

Samples 67 and 68 were examples of "storm water," and they yielded very bad results on bacteriological examination. Guinea-pigs inoculated subcutaneously with, in each case, 2 c.c. of samples 67 and 68 died on the third day. It has already been noted that the main storm water overflow works at less than twice the dry-weather flow.

Sample 78 consisted of subsoil water drawn from a trench 3 feet 6 inches deep. The water percolated through very fine white sand into the trench, according to Mr. Kershaw's notes, and this may account for the good results obtained. The sample contained no B. coli and no spores of B. enteritidis sporogenes in 1 c.c. There was a fish refuse heap about 100 yards away from the trench, and the nearest land under irrigation was about 150 yards distant. It is improbable, however, that the subsoil water was influenced by these circumstances.

Samples 71, 72, 73, 74 were, with the exception of 72 (general effluent) drawn from the Sinderland brook, which borders the farm and receives the effluent outfalls; 71 was drawn above the effluent outfalls, and 73 and 74 respectively 175 and 250 yards below the last effluent outfall. The ratio of the stream to the effluent was, at the time of collection, approximately 6 to 1, although normally the ratio is about 3 to 1. The brook water above the effluent outfalls was grossly polluted.* Below the effluent outfalls, it was naturally still more impure, and sample 74 (250 yards below the last effluent outfall) was as impure bacteriologically as sample 73 (175 yards below the last effluent outfall).

---

* It is not unimportant to possess some records of the bacterological quality of the rivers into which effluents are being discharged. The subject is one which must needs influence, to some extent, the question of practicable standards.

TABLE 5.—Showing the results of the bacteriological examination of samples of storm water overflow, brook water, effluent and subsoil water, obtained from Altrincham Sewage Farm.

Description of the Sample.	Total Number of bacteria per c.c.		Number of B. coli (or closely allied forms) per c.c.	Number of Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in m ilk cultures) per c.c
	Gelatine at 20° C.	Agar at 37° C.		
1.	2.	3.	4.	5.
67 Storm water overflow † - 29th April 1900.	17,600,000	1,480,000	100,000 - - - - (indol, + ·00001 c.c.)	+01, – ·001 c.c. At least 100 but less than 1,000
68 Same as above † - - (1 hour later) 29th April 1900.	26,100,000	1,640,000	10,000 not 100,000 - (indol, + ·00001 c.c.)	- ditto - ditto -
71 Sinderland brook water above effluent outfall * 7th May 1900.	53,000	6,700	At least 100 - - - (indol, + ·01 c c.)	+ ·1, – ·01 c.c. At least 10 but less than 100.
72 General effluent - - 7th May 1900.	960,000	26,000	1,000 - - - - (indol, + ·001 c.c.)	+1, – ·1 c.c. At least 1 but less than 10.
73 Sinderland brook + effluent, 7th May 1900. 175 yds. below last effluent outfall.	78,000	12,000	- ditto - ditto -	- ditto - ditto -
74 Same, lower down - - 7th May 1900. 250 yds. below last effluent outfall.	139,000	11,400	- ditto - ditto -	- ditto - ditto -
78 Subsoil water - - - 16th May 1900.	1,220	253	None in 1 c.c. - - (indol, + ·1 c.c.)	+10 c.c. – 1 c.c. None in 1 c.c.

Samples 67, 68, 71, 72, 73, 74, 78, yielded the following results as regards the "gas" test ("gas" in gelatine "shake" cultures in 24 hours at 20° C.) :—

67	+ ·01, – ·001 c.c.
68	+ ·001, – ·0001 c.c.
71	+ ·1, – ·01 c.c.
72	ditto.
73	ditto.
74	ditto.
78	negative 1 c.c.

* Volume of brook water to effluent was about 6 to 1 when samples were drawn, but normally the ratio is about 3 to 1.
† 2 c.c. were injected subcutaneously into a guinea-pig. The animal died on the third day.

General Conclusions. §

Judged as a whole, the results were certainly good, since the majority of the effluents passed the suggested standard for non-drinking water streams. From Mr. Kershaw's report, it appears that although part of the farm is peat land, this land is not used for irrigation purposes. The area actually irrigated, although containing some peat, is of a sandier character. It is possible that the peat land, although considered unsuitable for sewage purification purposes, may exercise some restraining influence on the multiplication of the bacteria. But the satisfactory results are probably to be ascribed to the porosity of the surface soil and the fine white sand and gravel which Mr. Kershaw describes as immediately subjacent to it. Moreover, the sewage was in some respects not very strong, and was doubtless diluted by subsoil water gaining access to the sewers. Further, the fact that the main storm overflow acted, when the sewage was increased to less than twice the dry-weather flow, placed during wet weather less burden on the land than is perhaps usually the case on most sewage farms. In this connection, the extremely foul character of samples 67 and 68 (storm water overflow) may well be borne in mind.

None of the effluents were in a fit state to be turned into a drinking-water stream.

The number of microbes (a) growing in agar at 37° C. as compared with the (b) total number (gelatine at 20° C.) was less than is usual in the case of sewage; and as regards the effluents, this difference was extremely well marked. The ratios of (a) to (b) being respectively about 1 to 9 (sewages) and 1 to 50 (effluents). Probably this may be regarded with safety as a satisfactory feature of the results.

§ For statistical information see tabular statement at the beginning of this Report, Section II.

Addendum A.—*Comparative records as regards* (1) *the "gas" and* (2) *B. enteritidis sporogenes tests of samples obtained from Altrincham as well as other sewage farms.*

These results are shown in the Table and Diagram illustrating Appendix III. (page 196), and they include all the samples (from other sewage farms as well as Altrincham) which were examined by both of these tests. 194 samples are dealt with altogether; of these 24 were obtained from Altrincham. Out of 15 samples of effluent, 9 passed the former and 11 the latter test. It may, therefore, be said that about two out of every three effluents proved satisfactory, as judged by the standard laid down for these tests.

Addendum B.—*General comparison as regards* (*a*) *the "gas,"* (*b*) *B. enteritidis sporogenes,* (*c*) *neutral-red broth, and* (*d*) *litmus milk tests, of samples obtained from Altrincham as well as other sewage farms.*

These results are shown in the Table and Diagram illustrating Appendix IV. (page 203), and they include all the samples (63 in number) which were examined by all (with a few exceptions) of these tests. Most of the samples, however, were obtained from Aldershot Camp sewage farm, and the Altrincham samples were but few in number. Of the four samples of effluent, and taking the tests in the above order, two, two, three, and two (out of three examined), respectively, passed the standards set up for these four tests.

Addendum C.—*Mr. Kershaw's abridged notes to accompany bacteriological data.*

ALTRINCHAM SEWAGE FARM.

Domestic Sewage.

Number of Sample.	Number of times the sewage is passed through or over the soil.	Area of plot or plots sewaged at the time of drawing Sample.	Length of time these plots had been sewaged previously to drawing Sample.	Nature of crops grown on plots.	Remarks.
		Acres.			
65	Once*	2·80	26 days*	Arable; no crops - -	Lagoon liquor* (surface), cloudy greenish colour, slight sewage smell; sewage running on continuously by day and night.
66	Twice	1·0	7 days (intermittently)	Ridged arable (sown mangolds).	Final effluent (filtration), iron film on surface, some red flocculent matter.
67	—	—	—	—	Liquor from storm overflow.
68	—	—	—	—	,, ,, ,, ,,
69	Once	2·80	30 days	Arable; no crops - -	Lagoon liquor (surface) cloudy.
70	Twice	1·0	2¼ hours	Ridged arable (sown mangolds).	Final effluent (filtration); sample taken after 4,000 gallons had passed on to the ridged land.
71	—	—	—	—	Brook water taken above effluent outfalls.
72	—	—	—	—	General effluent—turbid and reddish yellow colour.
73	—	—	—	—	Brook water and effluents taken 175 yards below last effluent outfall.
74	—	—	—	—	Brook water and effluents taken 250 yards below last effluent outfall.
76	Once	2·25	9½ hours	Osiers - - - -	Final effluent (filtration). This effluent was from night sewage.
77	Once	2·25	9½ hours	Osiers - - - -	Final effluent (filtration). This effluent was from night sewage.
78	—	—	—	—	Subsoil water drawn 3 ft. 6 in. deep—milky appearance, apparently full of lime.
248	Three times	2·50	18 hours	Arable; no crops - -	Final effluent (filtration), after passing through 3 lagoons (in series).
250	Three times	2·50	14 hours	Arable; no crops - -	Final effluent (filtration), after passing through 3 lagoons (in series).
251a	—	—	—	—	Brook water above effluent outfalls—brook in flood.
251	Once	5·0	5 hours	Osiers - - - -	Final effluent.
251b	Three times	2·50	10 hours	Arable; no crops - -	Final filtration lagoon effluent (as Nos. 248 and 250), red iron colour.
252	Once	·50	4 hours	Ridged arable - -	Final effluent, iron smell.
253	Once	5·0	11 hours	Osiers - - - -	Final effluent, fairly clear.
254	Once	4·0	4 hours	Osiers - - - -	Final effluent, some red flocculent suspended matter.
255	Three times	2·50	1 day	Arable; no crops - -	Final effluent (filtration) after passing through 3 lagoons (in series).
265	Once	·83	1 day	Arable; no crops - -	Liquor (surface) from 1st lagoon.
266	Twice	·83	1 day	Arable; no crops - -	Liquor (surface) from 2nd lagoon.
267	Three times	83	1 day	Arable; no crops - -	Liquor (filtration) from 3rd lagoon.
267a	—	—	—	—	Brook water taken 150 yards below last effluent outfall. Brook normal.
274	Three times	2·50	1 day	Arable; no crops - -	Final filtration effluent from lagoons, deep yellow colour—iron film.
274a	—	—	—	—	Brook water above effluent outfalls, tan refuse coming down.
275	Three times	2·50	2 days	Arable; no crops - -	Surface effluent from last lagoon, cloudy turbid colour, sewage smell.
276	Three times	2·50	2 days	Arable; no crops - -	Filtration effluent from last lagoon, yellow colour.
276a	—	—		—	Brook water taken below effluent outfalls. Water a dirty colour.

ALTRINCHAM SEWAGE FARM.

Domestic Sewage.

Number of sample.	Time of drawing sample.	Nature of sewage.	REMARKS.
64	10.15 a.m. - - -	Settled sewage - -	From catchpit or tank—very dilute.
75	11.30 a.m. - - -	,, ,, - -	From catchpit or tank—fairly strong.
249	10.45 a.m. - - -	,, ,, - -	From catchpit or tank—very dilute.
264	12 (noon) - - -	,, ,, - -	From catchpit or tank—fairly strong.

*COMPARATIVE SAMPLES (or samples taken from the same plots of land).

Lagoon effluents.	Other effluents.	REMARKS.
†(65)	(76)	* By "comparative samples" is meant, samples drawn from the same areas of land, and the effluents in brackets are comparable with each other so far as the areas of land sewaged is concerned.
†(69)	(77)	† These samples were from the surface liquor of the lagoon.
*(248)		* These samples were from the effluent which filtered to the drains underlying the three lagoons.
*(250)		
*(251)b		
*(255)		
*(267)		
*(274)		
*(276)		

ALTRINCHAM SEWAGE FARM.

DOMESTIC SEWAGE.

Number of Sample.	Date of drawing Sample.	Time of day.	Rainfall day previous to drawing Sample.	Rainfall day of drawing Sample.	Atmospheric Temperature time of drawing Sample.	Temperature of Sample.	Maximum Temperature during the 24 hours.	Minimum Temperature during the 24 hours	Humidity (9 a.m.)	Dissolved Oxygen in Sample.	Brief description of Sample.	REMARKS.
	1900:		Inches.	Inches.	C. F.	C. F.	C. F.	C. F.				
64	26 April -	10.15 a.m. -	·00	·01	—	9·4 (49)	15·0 (59)	5·5 (42)	—	—	Settled sewage.	*Mean daily max. temp. 16·4°C. (61·6°F.)
65	26 ,, -	11.30 ,, -	·00	·01	—	8·3 (47)	15·0 (59)	5·5 (42)	—	—	Lagoon effluent.	Mean daily min. temp. 4·1°C. (39·5°F.)
66	26 ,, -	12.15 p.m. -	·00	·01	—	8·3 (47)	15·0 (59)	5·5 (42)	—	—	Final ,,	Mean daily rainfall ·073.
67	29 ,, -	1 ,, -	·09	·10	—	10·0 (50)	15·5 (60)	6·6 (44)	—	—	Storm water.	*For the period 24th April to 15th May 1900.
68	29 ,, -	2 ,, -	·09	·10	—	10·5 (51)	15·5 (60)	6·6 (44)	—	—	,,	
69	30 ,, -	11.50 ,, -	·10	·00	—	13·3 (56)	15·5 (60)	0·0 (32)	—	—	Lagoon effluent.	*Note.*—Samples which may have been affected by rainfall are underlined.
70	30 ,, -	1.15 ,, -	·10	·00	—	8·8 (48)	15·5 (60)	0·0 (32)	—	—	Final ,,	
71	7 May -	11.45 a.m. -	·32	·00	—	11·1 (52)	20·5 (69)	3·3 (38)	—	—	Brook water.	§By "General" Effluent is meant a mixture of two or more finally treated effluents on leaving the farm.
72	7 ,, -	11.50 ,, -	·32	·00	—	11·1 (52)	20·5 (69)	3·3 (38)	—	—	§General effluent	
73	7 ,, -	12.5 p.m. -	·32	·00	—	11·1 (52)	20·5 (69)	3·3 (38)	—	—	Brook water and effluent.	
74	7 ,, -	12.15 ,, -	·32	·00	—	11·1 (52)	20·5 (69)	3·3 (38)	—	—	,, ,,	
75	15 ,, -	11.30 a.m. -	·00	·005	—	10·0 (50)	20·5 (69)	1·6 (35)	—	—	Settled sewage.	
76	15 ,, -	1 p.m. -	·00	·005	—	8·8 (48)	20·5 (69)	1·6 (35)	—	—	Final effluent.	
77	16 ,,	11.50 a.m. -	·005	·00	—	9·4 (49)	—	—	—	—		
78	16 ,, -	12.20 p.m. -	·005	·00	—	9·4 (49)	—	—	—	—	Subsoil water.	

ALTRINCHAM SEWAGE FARM—*continued.*

DOMESTIC SEWAGE—*continued.*

Number of Sample.	Date of drawing Sample.	Time of day.	Rainfall day previous to drawing Sample.	Rainfall day of drawing Sample.	Atmospheric Temperature time of drawing Sample.	Temperature of Sample.	Maximum Temperature during the 24 hours.	Minimum Temperature during the 24 hours.	Humidity (9 a.m.)	Dissolved Oxygen in Sample.	Brief description of Sample.	REMARKS.
	1901 :											
248	16 April	11.10 a.m.	·12	·20	6·1 (43)	5·5 (42)	1·1 (44)	—	98	—	Final lagoon effluent.	†Mean daily max. temp. 18·9°C. (65·9°F.) Mean daily min. temp. 4·7°C. (40·6°F.) Mean daily rainfall ·026 inch. Mean daily humidity 79·8
249	17 ,,	10.45 ,,	·20	·04	8·3 (47)	7·2 (45)	10·0 (50)	0·5 (33)	86	—	Settled sewage.	
250	17 ,,	12 (noon)	·20	·04	9·4 (49)	6·6 (44)	10·0 (50)	0·5 (33)	86	1 c.c.	Final effluent.	
251	17 ,,	12.30 p.m.	·20	·04	10·0 (50)	6·6 (44)	10·0 (50)	0·5 (33)	86	—	,, ,,	†For the period 16th April to 11th May 1901.
251a	18 ,,	2 ,,	·04	·00	12·2 (54)	8·3 (47)	13·8 (56)	5·5 (42)	93	—	Brook water.	
251b	19 ,,	11.15 a.m.	·00	·00	13·3 (56)	7·7 (46)	23·8 (75)	3·3 (38)	71	—	Final effluent.	
52	22 ,,	11.10 ,,	·00	·00	23·3 (74)	8·8 (48)	22·7 (73)	9·4 (49)	87	—	,, ,,	
253	22 ,,	11.20 ,,	·00	·00	22·3 (74)	8·8 (48)	22·7 (73)	9·4 (49)	87	—	,, ,,	
254	22 ,,	11.45 ,,	·00	·00	23·8 (75)	7·7 (45)	22·7 (73)	9·4 (49)	87	—	,, ,,	
255	22 ,,	12 (noon)	·00	·00	23·8 (75)	10·0 (50)	22·7 (73)	9·4 (49)	87	—	Lagoon effluent.	
264	30 ,,	12 (noon)	·00	·00	19·4 (67)	17·7 (64)	23·3 (74)	4·4 (40)	80	—	Settled sewage.	
265	30 ,,	12.30 p.m.	·00	·00	19·4 (67)	17·2 (63)	22·3 (74)	4·4 (40)	80	—	First lagoon liquor.	
266	30 ,,	1.30 ,,	·00	·00	20·0 (68)	16·6 (62)	22·3 (74)	4·4 (40)	80	—	Second ,, ,,	
267	1 May	10.45 a.m.	·00	·00	15·5 (60)	10·0 (50)	13·8 (57)	5·5 (42)	80	0·75	Final ,, ,,	
267a	1 ,,	11 ,,	·00	·00	16·1 (61)	10·5 (51)	13·8 (57)	5·5 (42)	80	3·50	Brook water and effluent.	
274	7 ,,	2.30 p.m.	·07	02	11·6 (53)	11·1 (52)	12·7 (55)	0·5 (33)	80	1·0	Final lagoon liquor.	
274a	7 ,,	3 ,,	·07	·02	11·1 (52)	11·1 (52)	12·7 (55)	0·5 (33)	80	2·0	Brook water and refuse.	
275	8 ,,	11.30 a.m.	·02	·03	13·8 (57)	10·0 (50)	19·4 (67)	7·2 (45)	93	—	Final lagoon liquor.	
276a	8 ,,	12 (noon)	·02	·03	13·3 (56)	10·0 (50)	19·4 (67)	7·2 (45)	93	2·0	Brook water and effluent.	
276	8 ,,	12.30 p.m.	·02	·03	12·7 (55)	10·0 (50)	19·4 (67)	7·2 (45)	93	0·50	Final effluent.	

Addendum C. (continued.)—*Mr. Kershaw's abridged notes to accompany the bacteriological data.**

ALTRINCHAM SEWAGE FARM.

(Domestic Sewage.)

ADDITIONAL NOTES ON SAMPLES.

Sample No. 65.—The lagoon from which this sample was drawn had been in use (at the time of drawing the sample) since April 1st, 1900.

Sample No. 66.—This effluent appeared to contain a large amount of iron, and the beds of streams in the neighbourhood are covered with a deep reddish-yellow ochreous deposit.

Sample No. 67.—This sample was drawn after the storm overflow had been running for 30 minutes. The brook into which the discharge took place was in a filthy condition owing to the paper and fæces flowing into it. ·10-inch rainfall in about 3½ hours on a saturated surface caused the overflow.

Samples No. 68.—This sample was drawn after the overflow had been working for 1½ hours.

Samples No. 69 and 70.—The sewage from which these samples were produced was very dilute owing to the rainfall the previous day. Sample No. 70 was from a plot which had been sewaged with lagoon liquor intermittently for 7 days. The sewage was run on for about 12 hours, then a rest of 12 hours, before any further sewaging. Rain appears to wash out yellow coloring matter from the under-drains.

Sample No. 71.—Brook water taken 13 yards above first effluent outfall. The brook was in flood, and the water turbid, a slight greasy film on the surface of the water.

Sample No. 72.—General effluent taken from both effluent outfalls. Volume of stream to effluent approximately as 6 to 1, effluent discoloured, reddish matter in suspension.

Sample No. 73.—Brook water and effluent taken 175 yards below last effluent outfall as the brook and effluent did not appear to mix thoroughly until that point was reached. There were large masses of sewage fungus discoloured with iron growing in the bed and sides of the stream.

Sample No. 76.—This effluent was from night sewage. The sewage takes a long time to pass through the osier beds, as the roots consolidate the ground.

Sample No. 77.—This sample was from the same sewage as No. 76, and also from the same plot previously sewaged, *i.e.*, the sewage in the grips between the osier beds had not yet all passed through to the under-drains.

Sample No. 78.—Subsoil water drawn from a trench sunk 3 ft. 6 in. deep. The water percolated into the hole through a stratum of very fine white sand, and was very milky in appearance.

Sample No. 248.—Final lagoon effluent after passing through three lagoons and filtering through to the under-drains. Effluent had a sewage and iron smell. The lagoons (3 in series), had previously been treating sewage intermittently for one month. The plot had been sewaged continuously for 18 hours before the sample was taken

Sample No. 251A.—Brook water taken above effluent outfalls; brook in flood owing to recent heavy rains.

Sample No. 251.—Final effluent from osier beds; these beds had been treated with crude sewage prior to passing through the settling tank. The beds had been sewaged intermittently throughout February (1901).

Sample No. 252.—The land from which this effluent was taken had not been sewaged since February (1901)

Sample No. 253.—This effluent was from settled sewage.

Sample No. 254.—This effluent was from crude sewage.

Sample No. 255.—Filtration effluent from lagoons.

Sample No. 265.—This effluent was taken from the surface of the first lagoon just before entering the second lagoon.

Sample No. 266.—This effluent was drawn in a similar manner as No. 265, but from the second lagoon.

Sample No. 267.—This effluent was a filtration one from the three lagoons.

Sample No. 267A.—Brook and effluent taken 150 yards below the last effluent outfall.

Sample No. 274A.—Brook water above effluent outfalls; some tan liquor was passing down the brook at the time.

Sample No. 274.—Filtration effluent from lagoons. This sample and No. 267 was taken after some old land drains had been stopped. There appeared previously to be a chance of the sewage having gained admission to the effluent through these drains.

Sample No. 275.—Surface effluent taken from the third lagoon, in a similar manner to Nos. 265 and 266.

Sample No. 276A.—Brook water, a dirty colour, and a good deal of sewage weed in the bed and sides of the stream.

---

* In a few instances samples referred to in this addendum are not accompanied by any bacteriological records. These samples were extra ones collected by Mr. Kershaw for chemical analysis.

SECTION III.

CAMBRIDGE SEWAGE FARM.

1. Situation of farm.—On the Milton Road, about 3 miles from Cambridge.

2. Total acreage of farm.—102·5 acres.

3. Total irrigable area.—74 acres.

4. Average area irrigated at one time.—18·5 acres

5. Population draining to farm.—50,000.

6. Population per acre irrigated.—675.

7. Gallons of sewage per head per day.—45.

8. Dry-weather flow of sewage per 24 hours.—2,250,000 gallons.

9. Gallons of sewage (exclusive of storm water) treated per acre per 24 hours.—121,600 = $(\frac{2250000}{18 \cdot 5})$.

10. Gallons of sewage treated per acre per 24 hours on the assumption that each acre of irrigable area is under sewage all the time (this for purposes of comparison) $(\frac{2250000}{74})$ = 30,400 gallons.

11. Characters of the sewage.—Mainly domestic (some brewery refuse).

12. Method of treatment.—Screening, settling tanks and land filtration.

13. General characters of the soil and subsoil.—Sandy loam overlying gravel and sand.

14. Separate or combined sewerage system.—Partially separate.

15. The final effluent is discharged into.—River Cam.

16. Number of years farm in operation before 1900.—5 years (systematic working).

A full description of Cambridge Sewage Farm will be found in Mr. Kershaw's report. (Part IV. Engineering and Practical Report.) It is necessary, therefore merely to allude here very briefly to some of the more important points, namely, as follows :—

The sewage is mainly domestic (some brewery refuse). The general characters of the soil and subsoil may be described as sandy loam overlying gravel and sand. The method of treatment is by screening, settling tanks, and land filtration. The sewerage system is partially separate. The storm overflows practically never come into operation; but the storm water does not directly affect the farm since it is pumped on to coarse clinker beds and then discharged into the river. The sludge is disposed of on the farm. The entire farm is under-drained. Most of the land is uncropped. The effluents discharge into the river Cam. A great deal of subsoil water finds its way into the sewers, but on the farm itself not much reaches the under-drains. Quoting from Mr. Kershaw's report :— "*The total acreage of the farm is* 102·5 *acres. The area actually irrigated is* 74 *acres, exclusive of an additional filtration area now being prepared. The whole* 74 *acres sewaged are arable. This area* (74 *acres*) *takes* (*excluding the question of storm water*) $2\frac{1}{4}$ *million gallons during the* 24 *hours. With a population of* 50,000 *persons this is equal to* 675·67 *persons per acre of irrigable area, or* 30,400 *gallons per acre* (*at* 45 *gallons of sewage per head*). *Approximately one-fourth of the total irrigable area is irrigated at one time, so that* 121,600 *gallons of sewage are treated per acre per* 24 *hours.*"

The following is a summary of the several sections of the report so far as it relates to Cambridge sewage farm ;—

1. Tabular statement and summary of the chief bacteriological results.

2. Diagram 4 illustrating the results shown in Table 6 with comments thereon.

3. Results considered in relation to Mr. Kershaw's notes.

4. Results in relation to tests other than B. enteritidis sporogenes.

5. Results of the examination of additional samples of subsoil water and river water.

6. General conclusions.

Addendum A.—Comparative records as regards (1) the "gas" and (2) B. enteritidis sporogenes tests of samples obtained from Cambridge as well as other sewage farms.

Addendum B.—Mr. Kershaw's abridged notes to accompany bacteriological data.

1. *Tabular statement and summary of the chief bacteriological results.*

The following table (Table 6) shows as regards the total number of bacteria, B. coli, and spores of B. enteriditis sporogenes, the results of the bacteriological examination of samples of sewage and effluent obtained from Cambridge Sewage Farm.

TABLE 6.—Showing, as regards the total number of bacteria, B. coli, and spores of B. enteritidis sporogenes, the results of the bacteriological examination of sewage and effluents obtained from Cambridge Sewage Farm.

Description of the Sample.	Total Number of bacteria per c.c.		Number of B. coli (or closely allied forms) per c.c.	Number of Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in milk culture) per c.c.
	Gelatine at 20° C.	Agar at 37° C.		
1.	2.	3.	4.	5.
201 Crude sewage - - - 12.20 a.m., 8th January 1901.	7,600,900	1,490,000	At least 10,000 -	+·01, –·001 c.c.. At least 100 but less than 1,000.
213 Settled sewage - - - 11.15 a.m., 23rd January 1901.	24,200,000	1,060,000	At least 100,000 -	- ditto - ditto.
215 Settled sewage - - - 11.15 a.m., 28th January 1901.	2,160,000	710,000	- ditto - -	- ditto - ditto.
217 Settled sewage - - - 2.30 p.m., 28th January 1901.	14,000,000	3,150,000	- ditto - -	- ditto - ditto.
Average - - -	11,990,000	1,602,500	[Ratio of Cols. 2 : 3=7·4 : 1]	
203 Final effluent - - - 11.25 a.m., 9th January 1901.	149,000	34,000	At least 1,000 -	+·1, –·01 c.c. At least 10 but less than 100.
204 General effluent - - - 12.15 p.m., 9th January 1901.	380,000	21,000	- ditto - -	- ditto - ditto.
205 General effluent - - - 11.45 a.m., 10th January 1901.	1,440,000	204,000	- ditto - -	+·01, –·001 c.c At least 100 but than 1,000.
207 General effluent - - - 11.30 a.m., 14th January 1901.	2,050,000	94,000	At least 10,000 -	+·1, –·01. At least 10 but less than 100.
208 General effluent - - - 11.15 a.m., 15th January 1901.	1,200,000	225,000	At least 1,000 -	- ditto - ditto.
209 General effluent - - - 11.40 a.m., 16th January 1901.	—	85,000	- ditto - -	- ditto - ditto.
210 Final effluent - - - 12.30 p.m., 16th January 1901.	62,200	1,080	At least 100 - -	- ditto - ditto.
211 Final effluent - - 1.45 p.m., 21st January 1901.	75,000	11,100	At least 1,000 -	+1, –·1 c.c. At least 1 but less than 10.
212 Final effluent - - - 4.45 p.m., 21st January 1901.	890,000	81,000	At least 10,000 -	+·1, –·01 c.c. At least 10 but less than 100.
214 General effluent - - - 1.15 p.m., 23rd January 1901	1,640,000	146,000	1,000 not 10,000 -	- ditto - ditto.
216 Final effluent - - - 12.50 p.m., 28th January 1901.	34,000	3,600	Less than 1,000 -	- ditto - ditto.
218 Final effluent - - - 4 p.m., 28th January 1901.	77,000	9,800	At least 1,000 -	+1, –·1 c.c. At least 1 but less than 10.
220 General effluent - - - 12.15 p.m., 4th February 1901.	1,070,000	158,000	1,000 not 10,000 -	+·1, –·01 c.c. At least 10 but less than 100.
221 General effluent - - - 11.30 a.m., 5th February 1901.	182,000	23,000	100 not 1,000 - -	- ditto - ditto.
Average - - -	711,476 [94% reduction]	78,327 [95% reduction]	[Ratio Cols. 2 : 3= 9 : 1]	

Brief Summary of the results shown in Table 6.

Crude Sewage and Settled Sewage :—

The samples presented the usual biological characters of sewage. Thus, the average results were as follows :—Total number of bacteria, over ten million (gelatine at 20° C.) and over one million (agar at 37° C.) respectively per c.c. B. coli at least 100,000, and B. enteritidis sporogenes at least 100 in 1 c.c.

Effluents :—

Total number of bacteria (gelatine at 20° C.) per c.c. :—Five samples contained more than one million, but less than ten million. Four samples between 100,000 and one million. Four samples over 10,000, but less than 100,000. [Provisional standard, less than 100,000 per c.c.]

Total number of bacteria (agar at 37 °C.) per c.c. :—Four samples contained more than 100,000, but less than one million. Seven samples between 10,000 and 100,000. Three samples over 1,000 but less than 10,000. [Provisional standard, less than 10,000 per c.c.

B. coli (and closely allied forms) per c.c. :—Two samples contained at least 10,000. Nine samples, 1,000 or more. One sample none in $\frac{1}{1000}$ c.c. Two samples, 100. [Provisional standard, less than 1,000 per c.c.]

Spores of B. enteritidis sporogenes per c.c. :—One sample contained at least 100 but less than 1,000. Eleven samples at least 10 but less than 100. Two samples at least 1 but less than 10. [Provisional standard, less than 10 per c.c.]

2. *Diagram* 4, *illustrating the results shown in Table* 6, *with comments thereon.*

The results are shown in graphic form in Diagram 4.

By referring to Diagram 4, it will be seen that certain horizontal lines are drawn indicating provisional standards (non-drinking water streams).

All samples according to these standards which did not fulfil the following requirements would be tentatively condemned :—

(1.) Total number of bacteria (gelatine at 20° C.)—less than 100,000 - - - - - - - - -
(2.) Total number of bacteria (agar at 37° C.)—less than 10,000 - - - - - - - - - - per c.c.
(3.) B. coli—less than 1,000 - - - - - - -
(4.) B. enteritidis sporogenes—less than 10 - - -

As regards (1) four out of 13 effluents proved satisfactory.
,, (2) three ,, 14 ,, ,, ,,
,, (3) three ,, 14 ,, ,, ,,
,, (4) two ,, 14 ,, ,, ,,

Although only about one in every four of the effluents passed the suggested standards, nearly all of them, when compared with the sewage before treatment, showed a high percentage purification.

Thus, taking the B. enteritidis sporogenes results as a ready means of gauging the degree of biological purification effected, it is to be noted that while all the samples of sewage yielded a positive result with $\frac{1}{100}$ c.c., this was the case with only one sample of effluent. All the other effluents either passed (two in number) or came within measurable distance of passing (eleven in number) the suggested standard (negative result $\frac{1}{10}$ c.c.). On the average, it may be said that the percentage degree of purification was 90 per cent.

3. *Results considered in relation to Mr. Kershaw's notes.*†

It appears from Mr. Kershaw's notes that samples 203, 210, 211, 212, 216, and 218 were comparative* samples and final effluents. It is worth noting that sample 210 yielded good results, although, it is seen from Mr. Kershaw's notes, that the plot was, as the result of 10 days' intermittent sewaging, covered with a surface layer of sludge. Possibly the satisfactory result is due to the fact that the presence of an upper layer of sludge checks the rate of filtration of the sewage through the soil. The effluents varied a good deal in their biological composition, but were, on the average, better in quality than the general effluents 204, 205, 207, 208, 209, 214, 220, 221.

The marked percentage degree of purification effected by the land treatment is well seen by comparing, in Diagram 4, sewage 213 with effluent 214, sewage 215 with effluent 216, and sewage 217 with effluent 218. These samples being in each case what Mr. Kershaw terms corresponding samples, *i.e.*, effluents drawn at such time after the sewage sample as to show, as far as possible, the degree of purification effected by the passage of the sewage through or over the land.

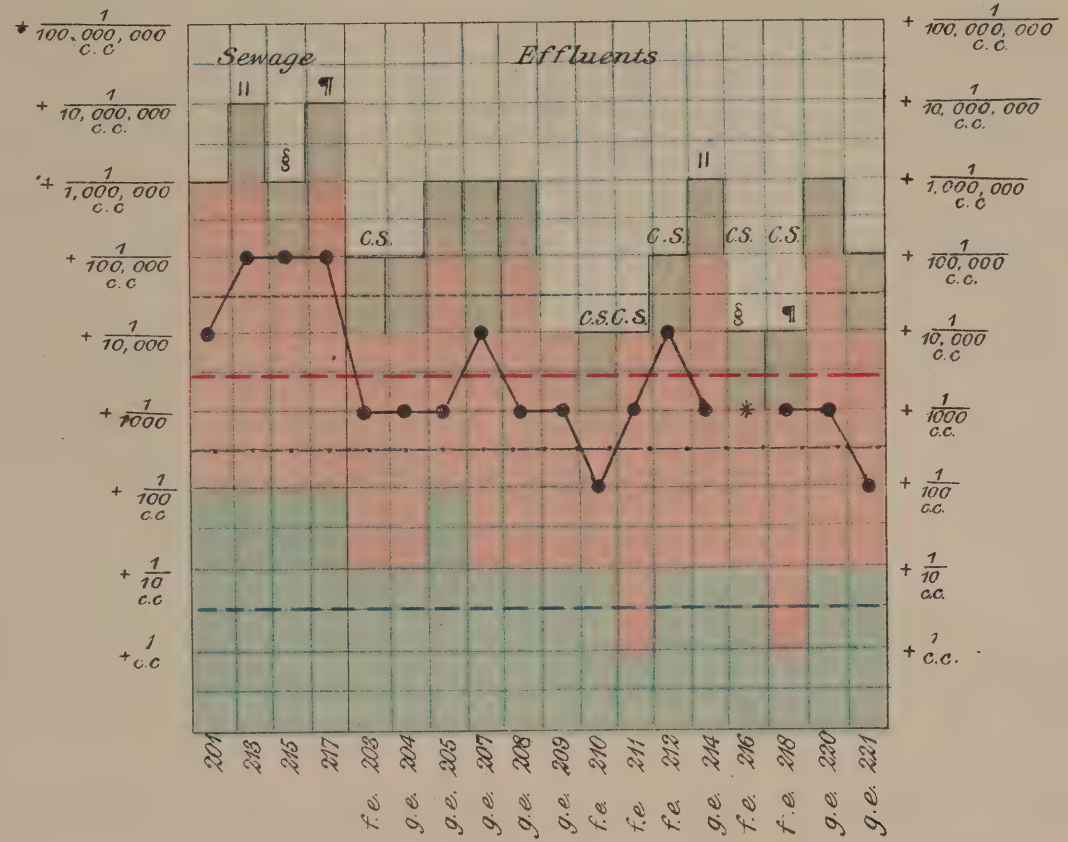
Although Mr. Kershaw's notes on the various effluents from the different sewage farms frequently throw much light on their observed biological characters, it sometimes happens, as might be anticipated, that his tentative anticipations run counter to the results obtained in the laboratory.

* By comparative samples is meant samples drawn from the same areas of land.
† Addendum B, page 61.

Diagram showing (1) the results of the bacteriological examination of samples of B. enteritidis sporogenes the results of the bacteriological examination of samples of sewage & of effluents obtained from Cambridge sewage farm.

= Total number of bacteria (gelatine at 20° c)
= " " " " (agar at 37° c)
B. Coli
B. Enteritidis sporogenes
* Less than 1000 B. Coli per c.c.

provisional standard (Four out of Thirteen effluents passed this standard) ($-\frac{1}{100,000}$ c.c.)
" (Three " " Fourteen " " " " ($-\frac{1}{10,000}$ c.c.)
" (" " " " " " " " ($-\frac{1}{1000}$ c.c.)
" (Two " " " " " " " " ($-\frac{1}{10}$ c.c.)



§ = Corresponding sample
|| = " "
¶ = " "

f.e. = Final effluent
g.e. = General "

C.S. = Comparative sample

3311 - 9. 02

Weller & Graham Ltd Litho. London.

Thus, from his notes sample 221 would be judged to be an exceptionally bad effluent, yet the bacteriological results showed it to be better than the average.

It appears from Mr. Kershaw's notes that the sewage is greatly diluted with subsoil water. This may possibly account for the fact that none of the sewage samples were found to contain more than 100 spores of B. enteritidis sporogenes per c.c.

An important point to be considered in connection with Cambridge sewage farm is that, as Mr. Kershaw points out in his report, most of the land is uncropped, and therefore acts as a bacterial filter.

4. *Results considered in relation to tests other than B. enteritidis sporogenes.*

So far chief stress has been laid on the results obtained from the B. enteritidis sporogenes test. As regards other tests, it will be seen that the average total number of bacteria in the sewage and effluents was as follows :—

—	Gelatine at 20° C. Microbes per c.c.	Agar at 37° C. Microbes per c.c.	Ratio.
Sewage - -	11,990,000	1,602,500	7·4 : 1
Effluents - -	711,476 (94 per cent. reduction)	78,327 (95 per cent. reduction)	9 : 1

Without question, these results represent a high percentage degree of purification, but the actual number of bacteria remaining in the effluents is considerably in excess of the suggested standards, viz., less than 100,000 (gelatine at 20° C.), and less than 10,000 (agar at 37° C.) bacteria per c.c.

These results seem to show that the reduction in the number of bacteria capable of growing at blood heat (37° C.) was somewhat greater than the total number of microbes (gelatine at 20° C.).

The B. coli results were fairly satisfactory, since no fewer than 12 out of 14 effluents either passed (3 in number) or came within measurable distance of passing (9 in number) the standard (negative result $\frac{1}{1000}$ c.c.).

In the Table and Diagram illustrating Appendix III. (page 196), the results as regards the "gas" and B. enteritidis sporogenes tests are brought into comparison. Of 14 effluents no less than eight passed the former, but only two the latter test. As the sewage samples yielded with both these tests the same results (+ ·01, − ·001 c.c.), it would seem that the gas-forming bacteria were removed or destroyed by the land treatment to a greater extent than the spores of B. enteritidis sporogenes.

Indol test (indol in broth cultures, five days at 37° C.)—

Sewage - -	Samples 213, 215, and 217 - - -	+ ·00001 c.c.
	Sample 201 - - - - - -	+ ·0001 c.c.
Effluents - -	Samples 214 and 220 - - - -	+ ·00001 c.c.
	Samples 204, 207, 208, 209, 211, 212, 221 - - - - - -	+ ·0001 c.c.
	Samples 203, 210, 216, 218 - -	+ ·001 c.c.

Judged by this test, the effluents were unsatisfactory.

Streptococci.—Sample 221 was examined for the presence of streptococci. A streptococcus (streptococcus 18) was isolated from $\frac{1}{100}$ c.c. (surface agar plate culture, 37° C.) of the sample. In broth it gave rise to diffuse cloudiness, and on microscopic examination was found to be a coccus forming chains, some short, others of medium length.

5. *Results of the bacteriological examination of additional samples of subsoil water and river water.*

The results of the examination of these samples is shown in Table 7.

It will be noted that the sample of subsoil water (219) contained neither B. coli nor spores of B. enteritidis sporogenes in 1 c.c. The sample was

drawn from a field in the neighbourhood of the farm, which was not in such a position as to be affected by the sewage farm.

As regards samples 222 and 223, the former was drawn above the effluent outfalls and the latter about 10 yards below the effluent outfall. The two samples did not, from the bacteriological point of view, differ from each other to any material extent. The river water above as well as below the effluent outfall was quite unfit for drinking purposes.

Table 7 showing the results of the bacteriological examination of certain samples obtained from Cambridge sewage farm.

Description of the Sample.	Total Number of bacteria per c.c.		Number of B. coli. (or closely allied forms) per c.c.	Number of Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in milk culture) per c.c.
	Gelatine at 20° C.	Agar at 37° C.		
1.	2.	3.	4.	5.
219* Subsoil water - - - 30th Jan. 1901.	4,300	230	None in 1 c.c. [Indol test. + 1, – ·1 c.c.]	– 1 c.c. Negative 1 c.c.
222* Cam river water above effluent outfall. 6th Feb. 1901.	38,000	1,400	10 not 100 [Indol + ·1, –·01 c.c.]	+ 1, – ·1 c.c. At least 1 but less than 10.
223* Cam river water + effluent. 6th Feb. 1901. Taken 10 yards below effluent outfall. Volume of effluent to river about 1 : 15 normally.	27,000	1,800	10 not 100 [Indol + ·01, –·001 c.c.]	- ditto - ditto.

* Samples 219, 222, 223, all yielded, as regards the "gas" test ("gas" in gelatine "shake" cultures in 24 hours at 20° C.), a negative result with 1 c.c.

6. *General Conclusions.*§

None of the effluents were in a fit state to be turned into a drinking-water stream. As regards non-drinking water rivers, the majority of the effluents failed to pass the suggested biological standards. But the percentage degree of purification effected in the effluents as compared with the crude sewage was striking; and as the majority of the effluents either passed or came within measurable distance of passing the standards laid down, there is no reason to doubt that land of the kind available at Cambridge could be worked so as uniformly to yield a satisfactory effluent. This would doubtless involve the acquisition of an additional area of land to treat the same volume of sewage; but the additional amount of land required for this purpose would not in all probability be so great as not to compensate by the improved condition of the effluent for the additional outlay. The very variable quality of the effluents, some being very good, others bad, suggests the possibility, if not the practicability, of obtaining by some means uniformly good results. As it appears from Mr. Kershaw's notes that the farm is very well managed, the acquisition of an additional area of land would seem to be the best solution of the problem.

It must be borne in mind that, although the sewage was dilute, the volume of sewage treated per acre was exceptionally great.

ADDENDUM A.—*Comparative records as regards* (1) *the "gas" test and* (2) *B. enteritidis sporogenes tests of samples obtained from Cambridge as well as other sewage farms.*

These results are shown in the Table and Diagram illustrating Appendix III. (page 196), and they include all the samples (from other sewage farms as well as Cambridge) which were examined by both of these tests. 194 samples are dealt with altogether, 18 of these being Cambridge samples. Of the 14 effluents no less than eight passed the "gas" test, but only two passed the B. enteritidis sporogenes test. As the four samples of sewage examined yielded exactly similar results (+ ·01 ; - ·001c.c.) with both of these tests, it may be concluded that the land treatment had effected a proportionately greater removal or destruction of the gas-forming bacteria than of the spores of B. enteritidis sporogenes.

§ For statistical information see tabular statement at the beginning of this report, Section III.

Addendum B.—*Mr. Kershaw's abridged notes to accompany the bacteriological data.**

CAMBRIDGE SEWAGE FARM.

ADDITIONAL NOTES ON DIFFERENT SAMPLES.

Sample No. 201.—Screened sewage not having passed through the settling tank, *i.e.*, only roughly screened at the pumping station before being pumped; a weak sample, apparently containing a large quantity of subsoil water.

Sample No. 202.—Corresponding final effluent to sewage No. 201; sample appeared very fairly clear, and had a very faint smell on shaking.

Sample No. 203.—The final effluent was from the same plot as No. 202, and was from a very dilute sewage; the plot was covered with a sheet of ice. The sewage had been applied continuously for 28 hours. The sample was clear, and had a very slight smell. Heavy snow (·08 inch melted) fell during the day, diluting the sewage.

Sample No. 204.—General effluent, fairly clear, very slight smell, some suspended matter, probably effected by the snow (·08 inch) during the day.

Sample No. 205.—General effluent, as No. 204, but hardly so clear.

Sample No. 205A.—River Cam water taken above the effluent outfall, river slightly above the normal height, a clear sample, river apparently in fair condition.

Sample No. 205B.—Screened and settled sewage, very dilute, a large amount of grease coming down.

Sample No. 205C.—Corresponding final effluent to No. 205B; ice disappeared from plot irrigated.

Sample No. 207.—General effluent, slight iron smell, some flocculent red matter (sewage weed disintegrated ?), probably washed from drains by increase of effluent following rainfall.

Sample No. 208.—General effluent, slight iron smell on shaking. This is apparently a fair average sample of the general effluent for the time of year.

Sample No. 209.—General effluent, some fragments of sewage weed, rather cloudy. Some of the plots becoming rather thickly coated with sludge on the surface.

Sample No. 209A.—River water drawn above effluent outfall, river normal, a clear sample, and apparently well oxygenated.

‖ Sample No. 210.—Final effluent, clear, no smell, plot with an average coating of sludge $\frac{3}{8}$ inch thick (after 10 days intermittent sewaging).

Sample No. 210A.—Final effluent, clear, no smell; the sewage going on to the plot was much stronger than usual, and of a dark brown colour.

Sample No. 211.—Final effluent drawn when the effluent was running freely away from the drains.

Sample No. 212.—Final effluent, as above, but after being held in contact with the land for $2\frac{1}{4}$ hours. The sewage running on to the plot sewaged was, however, apparently stronger from 1 p.m. to 2 p.m. than from 11 a.m. to 12.30 p.m.

Sample No. 213.—Screened and settled sewage, dilute.

Sample No. 214.—General effluent, suspended matter, very slight smell.

Sample No. 214A.—River water taken 100 yards below effluent outfall, river normal height, 6 c.c. oxygen in sample taken immediately below outfall; 6·50 c.c. 90 yards further down stream. A fairly clear sample.

Sample No. 214B.—General effluent, slightly cloudy, slight smell, some plots requiring a rest.

Sample No. 215.—Screened and settled sewage, weak.

Sample No. 216.—Final effluent, clear, no smell.

Sample No. 217.—Screened and settled sewage (strong), taken later in the day than previous samples to show the hourly variations in strength.

Sample No. 218.—Final effluent, clear, no smell, hardly any suspended matter.

Sample No. 219.—Subsoil water taken from a land drain at the outcrop of the gault in the neighbourhood of the farm, but which was not in such a position as to be effected by the sewage farm: apparently pure, no suspended matter, bright and sparkling.

Sample No. 220.—General effluent, cloudy, slight smell.

Sample No. 221.—General effluent, very cloudy, strong sewage smell, apparently worst effluent drawn from farm, snow (·05 inch) stirred up silt from surface of plots at bottom of farm.

Sample No. 222.—River water taken above effluent outfall, river normal, 7 c.c., by oxygen test.

Sample No. 223.—River water and effluent taken 10 yards below effluent outfall, 5·50 c.c. by oxygen test.

---

* In a few instances samples are referred to in this addendum concerning which there are no bacteriological records. These were extra samples, collected by Mr. Kershaw for chemical analysis.

‖ This coating of sludge seemingly acts as the "felt" on the surface of a water filter. The sewage has a tendency to spread evenly over the surface of the plot, filtration apparently commencing when the head of water on the soil is sufficiently deep to overcome the resistance of the sludge. From this it would appear that the whole of the plot does its work more equally than when this coating of sludge is absent.

Sewage Samples.

Domestic + Brewery (small amount) Sewage.

Number of Sample.	Nature of Sewage.	Source.	Time taken.	Remarks.
201	Screened sewage	—	12.20 p.m.	Taken before passing through settling tank.
205B	Screened and settled sewage.	Very weak -	11.15 a.m.	„ after „ „ „ „
213	Screened and settled sewage.	„ dilute -	11.15 a.m.	„ „ „ „ „ „
215	Screened and settled sewage.	„ „ -	11.15 a.m.	„ „ „ „ „ „
217	Screened and settled sewage.	Fairly strong -	2.30 p.m.	„ „ „ „ „ „

* Comparative Samples or Samples taken from the same plots of land.

Number of Samples.	Remarks.
No. 202 „ 203 „ 205c „ 210 „ 211 „ 212 „ 216 „ 218 - - - -	* By comparative samples is meant samples drawn from the same areas of land, and the effluents in brackets are comparable with each other so far as the area of land is concerned.

DOMESTIC SEWAGE.

Number of Sample.	Date of drawing Sample.	Time of day.	Rainfall day previous to drawing Sample.	Rainfall day of drawing Sample.	Air Temperature time of drawing Sample.	Temperature of Sample.	Maximum Temperature during the 24 hours.	Minimum Temperature during the 24 hours.	Humidity (9 a.m.)	Dissolved Oxygen in Sample. C.C.S.	Brief description of Sample.	REMARKS.
	1901:		Inches.	Inches.	°C. °F.	°C. °F.	°C. °F.	°C. °F.				
201	6 January -	12.20 p.m.	·00	·01 (snow).	0·5 (33)	6·6 (44)	0·0 (32)	−5·5 (22)	—	—	Sewage.	Mean daily maximum temperature, 5·1 °C (41·3° F.)
202	8 ,, - -	1.30 p.m.	·00	·01 (snow).	2·2 (36)	6·1 (43)	0·0 (32)	−5·5 (22)	—	3·75	Effluent.	Mean daily minimum temperature, ·4° C. (32·7° F.)
203	9 ,, - -	11.25 a.m.	·01 (snow).	·08 (snow).	0·0 (32)	5·5 (42)	3·8 (39)	0·0 (32)	—	0·75	,,	Mean daily humidity, 86·7 %
204	9 ,, - -	12.15 p.m.	·01 (snow).	·08 (snow).	0·0 (32)	5·5 (42)	3·8 (39)	0·0 (32)	—	1·25	§General effluent.	Mean daily rainfall, ·021 ″
205	10 ,, - -	11.45 a.m.	·08 (snow).	·01	5·5 (42)	4·4 (40)	9·4 (49)	0·5 (33)	92	6·25	,, ,,	For the period 7th January 1901 to 6th February 1901.
205a	10 ,, - -	12 (noon)	·08 (snow).	·01	5·5 (42)	5·0 (41)	9·4 (49)	0·5 (33)	92	1·50	River water.	NOTE.—Samples which may have been affected by rainfall or snow are underlined.
205b	12 ,, - -	11.15 a.m.	·00	·00	5·0 (41)	10·0 (50)	10·0 (50)	3·3 (38)	95	—	Sewage.	§ By "General" effluent is meant a mixture of two or more finally treated effluents on leaving the farm.
205c	12 ,, - -	12.20 p.m.	·00	·00	5·0 (41)	5·5 (42)	10·0 (50)	3·3 (38)	95	1·00	Effluent.	
207	14 ,, - -	11.30 a.m.	·00	·00	5·5 (42)	5·0 (41)	5·0 (41)	−2·7 (27)	76	2·50	General effluent.	
208	15 ,, - -	11.15 a.m.	·00	·00	1·6 (35)	5·0 (41)	3·3 (38)	2·2 (36)	90	2·75	,, ,,	
209	16 ,, - -	11.40 a.m.	·00	·00	4·4 (40)	4·4 (40)	9·4 (49)	4·4 (40)	91	2·00	,, ,,	
209a	16 ,, - -	12 (noon)	·00	·00	4·4 (40)	2·2 (36)	9·4 (49)	4·4 (40)	91	7·00	River water.	
210	16 ,, -	12.30 p.m.	·00	·00	5·5 (41)	5·5 (42)	9·4 (49)	4·4 (40)	91	3·75	Effluent.	
210a	18 , - -	2.40 p.m.	·09	·03	7·2 (45)	6·1 (43)	7·2 (45)	7·2 (45)	93	3·00	,,	
211	21 ,, - -	1.45 p.m.	·00	·00	11·1 (52)	6·6 (44)	11·1 (52)	7·7 (46)	93	4·00	,,	
212	21 - -	4.45 p.m.	·00	·00	10·5 (51)	5·5 (42)	11·1 (52)	7·7 (46)	93	1·25	,,	

CAMBRIDGE SEWAGE FARM.—DOMESTIC SEWAGE.—(Continued).

Number of Sample.	Date of drawing Sample.	Time of day.	Rainfall day previous to drawing Sample.	Rainfall day of drawing Sample.	Air Temperature time of drawing Sample.	Temperature of Sample.	Maximum Temperature during the 24 hours.	Minimum Temperature during the 24 hours.	Humidity 9 a.m.	Dissolved Oxygen in Sample CCS.	Brief description of Sample.	Remarks.
	1901:		Inches.	Inches.	°C. °F.	°C. °F.	°C. °F.	°C. °F.				
213	23 January -	11.15 a.m.	·00	·00	5·5 (42)	10·0 (50)	5·5 (42)	·0 (32)	98	—	Sewage.	
214a	23 „ - -	12.30 p.m.	·00	·00	5·5 (42)	5·5 (42)	5·5 (42)	·0 (32)	98	6·0	River water and effluent.	
214	23 „ - -	1.15 p.m.	·00	·00	6·1 (43)	5·5 (42)	5·5 (42)	·0 (32)	98	0·50	General effluent.	
214b	26 „ - -	12.45 p.m.	·03	·00	5·5 (42)	5·5 (42)	4·4 (40)	1·1 (34)	77	1·25	„ „	
215	28 „ - -	11.15 a.m.	·22	·02 (snow).	2·2 (36)	10·0 (50)	1·1 (34)	−1·1 (30)	91	—	Sewage.	
216	28 „ -	12.50 p.m.	·22	·02 (snow).	3·3 (38)	6·1 (43)	1·1 (34)	−1·1 (30)	91	1·50	Effluent.	
217	28 „ -	2.30 p.m.	·22	·02 (snow).	3·03 (38)	10·0 (50)	1·1 (34)	−1·1 (30)	91	—	Sewage.	
218	28 „ - -	4.0 p.m.	·22	·02 (snow).	0·5 (33)	6·1 (43)	1·1 (34)	−1·1 (30)	91	2·75	Effluent.	
219	30 „ - -	11.30 a.m.	·01 (snow).	·00	2·2 (36)	6·6 (44)	2·2 (36)	−2·2 (28)	91	3·50	Subsoil water.	
220	4 February -	12.15 p.m.	·00	·05 (snow).	0·0 (32)	4·4 (40)	0·5 (33)	−1·6 (29)	89	·25	General effluent.	
221	5 „ - -	11.30 a.m.	·05 (snow).	·05 (snow).	1·1 (34)	4·4 (40)	2·2 (36)	−1·1 (30)	98	0·50	„ „	
222	6 „ - -	12 (noon)	·05 (snow).	·00	2·2 (36)	1·1 (34)	2·7 (37)	0·0 (32)	95	7·00	River water.	
223	6 „ - -	12.15 p.m.	·05 (snow).	·00	2·7 (37)	1·1 (34)	2·7 (37)	0·0 (32)	95	5·50	River water and effluent.	
	1902.											
475	25 February -	Noon Mon. to 11 a.m. Tues.	·08	·19	—	—	—	—	—	—	Screened and settled sewage	24 hours samples.
476	26 „	Noon Tues. to 11 a.m. Wed.	·19	·00	—	—	—	—	—	—	„ „ „	
477	27 „	Noon Wed. to 11 a.m. Thurs.	·00	·10	—	—	—	—	—	—	„ „ „	

CAMBRIDGE SEWAGE FARM.

EFFLUENTS.

Number of Sample.	Number of times treated.	Area of plot or plots sewaged.	Period sewaged previously to drawing sample.	Nature of crops grown on plots.	REMARKS.
		A. R. P.	Hours.		
202	Once	*4 3 22	$4\frac{1}{2}$	None	*This plot was last sewaged on 2nd January 1901; "$\frac{1}{4}$" sludge on surface of plot.
203	,,	4 3 22	26	,,	
204	,,	About 20 acres	Various periods	,,	General effluent.
205	,,	,, ,, ,,	,, ,,	,,	,, ,,
205c	,,	4 3 22	24	,,	
207	,,	—	Various periods	,,	General effluent.
208	,,	—	,, ,,	,,	,, ,,
209	,,	—	,, ,,	,,	,, ,,
210	,,	4 3 22	$3\frac{1}{2}$	,,	
210a	,,	4 3 22	6	,,	
211	,,	4 3 22	$4\frac{3}{4}$	,,	
212	,,	4 3 22	$7\frac{3}{4}$	,,	
214	,,	—	Various periods	,,	General effluent.
214b	,,	—	,, ,,	,,	,, ,,
216	,,	4 3 22	4	,,	
218	,,	4 3 22	7	,,	
220	,,	—	Various periods	,,	General effluent.
221	,,	—	,, ,,	,,	,, ,,

*CORRESPONDING EFFLUENTS.

NUMBER OF SAMPLES.	REMARKS.
Samples Nos. 201 and 202 205b and 205c 215 and 216 213 and 214 217 and 218	**i.e.*, Effluents corresponding to screened or settled sewage in each case; that is to say, that the effluent is taken some time after the sewage sample to shew, as far as possible, the degree of purification effected on that particular sewage.

SECTION IV.

CROYDON (Beddington) SEWAGE FARM.

1. Situation of farm.—Beddington, about 3 miles from Croydon.

2. Total acreage of farm.—673·5.

3. Total irrigable area.—420 acres.

4. Average area irrigated at one time.—70 acres.

5. Population draining to farm.—100,000.

6. Population per acre irrigated.—238.

7. Gallons of sewage per head per day.—40 gallons.

8. Dry-weather flow of sewage per 24 hours.—4,000,000 gallons.

9. Gallons of sewage (exclusive of storm water) treated per acre per 24 hours.—57,100 = $(\frac{4000000}{70})$.

10. Gallons of sewage treated per acre per 24 hours, on the assumption that each acre of irrigable area is under sewage all the time. (This for purposes of comparison) $(\frac{4000000}{420}) = 9{,}500$ gallons.

11. Characters of the sewage.—Almost purely domestic.

12. Method of treatment.—(*a*) Croydon : screening, surface irrigation, and a little filtration. (*b*) Norbury: as above, but slight settlement in tanks in addition.

13. General characters of the soil and subsoil.—Gravelly loam overlying gravel and sand.

14. Separate or combined sewerage system.—Partially separate.

15. The final effluent is discharged into.—River Wandle.

16. Number of years farm in operation before 1900.—39 years.

A full description of Croydon (Beddington) sewage farm will be found in Mr. Kershaw's report (Part IV. Engineering and Practical). It is therefore necessary merely here to allude very briefly to some of the more important points mentioned in his report, namely, as follows :—

The soil may be described as a gravelly loam overlying gravel and sand. The sewage is almost purely domestic. The amount of subsoil water gaining access to the sewers is not great, and there is not much subsoil water on the farm. Mr. Kershaw rightly lays great stress on the fact that there are no storm overflows and the whole of the storm water is treated on the farm. In heavy storms, the sewage flow at the farm sometimes reaches 4½ times the normal dry weather flow. About half the area sewered is on the separate system. The sludge is ploughed into the land. Speaking in general terms, the method of treatment may be described as screening ,surface irrigation, and a little filtration. The sewage is passed over the land three or four times. Only about one-fourth part of the irrigable area is under-drained. The effluents are discharged into the river Wandle; the ratio of effluent to river water is about 1 to 8. Mangolds, cabbages, and oats are grown on the farm, but the staple crop is rye-grass. The gross area of the farm is 673·5 acres, the irrigable area 420 acres. The irrigable "*area (excluding the storm water) deals with four million gallons of sewage per* 24 *hours throughout the year. With a population of* 100,000 *this gives* 238 *persons per acre of irrigable area, or about* 9,520 *gallons per acre. during a normal sewage flow. As about one-sixth of this irrigable area is under sewage at once, this is equal to* 57,100 *gallons of sewage treated per acre per* 24 *hours.*"

The following is a summary of the several sections of the Report in so far as it relates to Beddington sewage farm :—

1. Tabular statement, and summary of the chief bacteriological results.

2. Diagram 5 illustrating the results shown in Table 8 with comments thereon.

3. Results considered in relation to Mr. Kershaw's notes.

4. Results considered in relation to tests other than the B. enteritidis sporogenes test.

5. Results of the bacteriological examination of additional samples of river water and mixed river water and effluent.

6. General conclusions.

Addendum A.—Results of the examination by means of simple tests of samples obtained from Beddington sewage farm (special comparative series of experiments).

Addendum B.—Comparative records as regards (1) the "gas" and (2) B. enteritidis sporogenes tests of samples obtained from Beddington, as well as other sewage farms.

Addendum C.—Additional bacteriological notes.

Addendum D.—Mr. Kershaw's abridged notes to company bacteriological data.

1. *Tabular statement, and summary of the chief bacteriological results.*

The following table (Table 8) shows as regards the total number of bacteria, B. coli and spores of B. enteritidis sporgenes, the results of the bacteriological examination of six samples of sewage, and twenty-two samples of effluents.

TABLE 8.—Showing as regards the total number of bacteria, B. coli, and spores of B. enteritidis sporogenes, the results of the bacteriological examination of sewage and effluents obtained from Beddington sewage farm.

	Description of the Sample.	Total number of bacteria per c.c.		Number of B. coli (or closely-allied forms) per c.c.	Number of Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in milk cultures) per c.c.	
		Gelatine at 20° C.	Agar at 37° C.			
	1.	2.	3.	4.	5.	
36	Screened sewage - - - 12.15 p.m., 12th Feb. 1900.	23,900,000	2,970,000	At least 100,000 -	+ ·01, – ·001 c.c. At least 100 but less than 1,000.	
40	Screened sewage - - - 11.45 a.m, 20th Feb. 1900.	22,200,000	4,020,000	ditto - -	+ ·001, – ·0001 c.c. At least 1,000 but less than 10,000.	
149	Screened and settled sewage. 11.45 a.m., 3rd Oct. 1900.	30,400,000	7,240,000	- ditto - -	- ditto - ditto.	
152	Screened and settled sewage. 11 a.m., 8th Oct. 1900.	39,000,000	10,560,000	- ditto - -	- ditto - ditto.	
158	Screened sewage - - - 12 noon, 17th Oct. 1900.	44,400,000	4,840,000	- ditto - -	+ ·001 c.c. At least 1,000.	
161	Screened sewage - - - 12.15 p.m., 24th Oct. 1900.	14,100,000	2,260,000	- ditto - -	+ ·001, – ·0001 c.c. At least 1,000 but less than 10,000.	
	Averages - - -	29,000,000	5,315,000	[Ratio of cols, 2 : 3 = 5·4 : 1.]		
37	First field effluent - - 2.45 p.m., 12th Feb. 1900.	10,200,000	1,210,000	At least 100,000 -	+ ·001 c.c. At least 1,000.	1st Visit, February 1900.
38	Second field effluent - - 4.30 p.m., 12th Feb. 1900.	4,800,000	190,000	10,000 not 100,000 -	+ ·01, – ·001 c.c. At least 100 but less than 1,000.	1st Visit, February 1900.
39	Final effluent - - - 5.15 p.m., 12th Feb. 1900.	3,100,000	60,000	At least 1,000 -	+ ·1, – ·01 c.c. At least 10 but less than 100.	1st Visit, February 1900.
41	First field effluent - - 1.15 p.m., 20th Feb. 1900.	19,300,000	390,000	10,000 not 100,000 -	+ ·01, – ·001 c.c At least 100 but less than 1,000.	1st Visit, February 1900.
42	Second field effluent - - 2.50 p.m., 20th Feb. 1900.	610,000	7,900	1,000 not 10,000 -	+ ·1, — ·01 c.c. At least 10 but less than 100.	1st Visit, February 1900.
43	Final effluent - - - 4 p.m., 20th Feb. 1900.	51,000	900	100 not 1,000 - -	+ 1, – ·1 c.c. At least 1 but less than 10.	1st Visit, February 1900.
44	General effluent - - - 4.35 p.m., 26th Feb. 1900.	169,000	7,400	1,000 not 10,000 -	+ ·01, – ·001 c.c. At least 100 but less than 1,000.	1st Visit, February 1900.
150	First field effluent - - 2 p.m., 3rd Oct. 1900.	9,520,000	2,752,000	10,000 not 100,000 -	- ditto - ditto.	2nd Visit, October 1900.
151	Final effluent - - - 3.30 p.m., 3rd Oct. 1900.	5,920,000	496,000	- ditto - -	+ ·1, – ·01 c.c. At least 10 but less than 100.	2nd Visit, October 1900.
153	Final effluent - - - 2.30 p.m., 8th Oct. 1900.	133,000	8,600	100 not 1,000 - -	+ ·01, – ·001 c.c. At least 100 but less than 1,000.	2nd Visit, October 1900.
154	Final effluent - - - 2 p.m., 9th Oct. 1900.	106,000	3,200	At least 100 - -	– ·1 c.c. None in $\frac{1}{10}$ c.c.	2nd Visit, October 1900.
155	Final effluent - - - 1.45 p.m., 10th Oct. 1900.	90,000	7,700	- ditto - -	+ 1, – ·1 c.c. At least 1 but less than 10.	2nd Visit, October 1900.
156	Final effluent - - - 2.45 p.m., 15th Oct. 1900.	440,000	101,000	10,000 not 100,000 -	+ ·1 – ·01 c.c. At least 10 but less than 100.	2nd Visit, October 1900.
157	Final effluent - - - 12.45 p.m., 16th Oct. 1900.	43,000	1,600	10 not 100 - -	+ 1, – ·1 c.c. At least 1 but less than 10.	2nd Visit, October 1900.
159	Final effluent - - - 5 p.m., 17th Oct. 1900.	4,080,000	436,000	10,000 not 100,000 -	- ditto - ditto.	2nd Visit, October 1900.
162	First effluent, experiment - 2.30 p.m. 24th Oct. 1900.	1,060,000	294,000	At least 10,000 -	+ ·1, – ·01 c.c. At least 10 but less than 100.	3rd Visit, Oct. and Nov. 1900. Experimental Effluents.
164	Final effluent, experiment - 12.45 p.m., 24th Oct. 1900.	17,200	5,000	At least 100 - -	None in 1 c.c.	3rd Visit, Oct. and Nov. 1900. Experimental Effluents.
164B	First effluent, experiment 12.45 p.m., 31st Oct. 1900.	1,400,000	428,000	At least 10,000	+ ·1, – ·01 c.c. At least 10 but less than 100.	3rd Visit, Oct. and Nov. 1900. Experimental Effluents.
165	Final effluent, experiment - 1 p.m., 31st Oct. 1900.	210,000	45,000	At least 100 - -	None in 1 c.c.	3rd Visit, Oct. and Nov. 1900. Experimental Effluents.
166	Final effluent, experiment - 12.40 p.m., 2nd Nov. 1900.	1,680,000	216,000	At least 1,000 -	+ 1, – ·1 c.c. At least 1 but less than 10.	3rd Visit, Oct. and Nov. 1900. Experimental Effluents.
169	Final effluent, experiment - 12.40 p.m., 6th Nov. 1900.	116,000	10,900	At least 100 - -	- ditto - ditto.	3rd Visit, Oct. and Nov. 1900. Experimental Effluents.
172	Final effluent, experiment - 3.15 p.m., 9th Nov. 1900.	2,350,000	404,000	1,000 not 10,000 -	+ ·01, – ·001 c.c. At least 100 but less than 1,000.	3rd Visit, Oct. and Nov. 1900. Experimental Effluents.
	Averages, inclusive of the first and second field and experimental effluents.	2,972,509 [89% reduction]	321,600 [93% reduction]	1 : 9·2 [Ratio of cols. 2 to 3 = 9·2 : 1.]		
	Averages, exclusive of the first and second field and experimental effluents.	1,413,200 [95% reduction]	112,240 [97% reduction]	[Ratio of cols. 2 to 3 = 12 : 1.]		

The following is a brief summary of the results shown in Table 8 :—

Sewages :—

The total number of bacteria in gelatine at 20°C., and agar at 37°C. was on the average over ten million but less than one hundred million, and over one million but less than ten million respectively per c.c.

The number of B. coli was, in each instance, at least 100,000 per c.c. The number of spores of B. enteritidis sporogenes varied from 100 to 1,000 (usually 1,000) in 1 c.c.

Effluents :—

The effluents varied greatly in their biological composition.

Total number of bacteria (gelatine at 20°C.) in 1 c.c. :—In two samples the number was over ten million. In nine samples over one but less than ten million. In seven samples between 100,000 and one million. In four samples more than 10,000 but less than 100,000. [Provisional standard, less than 100,000 per c.c.]

Total number of bacteria (agar at 37°C.) in 1 c.c. :—In two samples the number was over one million but less than ten million. In nine samples over 100,000 but less than one million. In three samples between 10,000 and 100,000. In seven samples between 1,000 and 10,000. In one sample over 100 but less than 1,000. [Provisional standard, less than 10,000 per c.c.]

Number of B. coli per c.c. :—In one sample the number was at least 100,000. In eight samples, at least 10,000. In five samples at least 1,000. In seven 100. In one 10. [Provisional standard, less than 1,000 per c.c.]

Spores of B. enteritidis sporogenes :—In one sample the number was at least 1,000. In six samples at least 100. In six samples at least 10. In six samples at least 1. In one sample less than 10. In two samples none in 1 c.c. [Provisional standard, less than 10 per c.c.]

2. *Diagram 5 illustrating the results shown in Table 8, with comments thereon.*

The results are shown in graphic form in Diagram 5. By referring to the Diagram 5 it will be seen that certain horizontal lines are drawn indicating provisional standards (non-drinking water streams).

All samples which, according to these standards, did not fulfil the following requirements would be tentatively condemned :—

1. Total number of bacteria (gelatine at 20° C.) Less than 100,000
2. Total number of bacteria (agar at 37° C.) Less than 10,000 -
3. B. coli. Less than 1,000 - - - - - - -
4. B. enteritidis sporogenes. Less than 10 - - - - -

} per c.c.

As regards (1) four out of 22 effluents - - - -
,, ,, (2) eight ,, ,, - - - -
,, ,, (3) eight ,, ,, - - - -
,, ,, (4) nine ,, ,, - - - -

} passed the above standards.

Judged by these standards the majority of the effluents proved unsatisfactory; but it is worth noting that a considerable proportion of these effluents came within *measurable distance* of passing the arbitrary standards provisionally adopted, and some of the samples were undeniably satisfactory.

This, as regards tests (1) (2) (3) (4), if the standard be lowered to less than 1 million, less than 100,000; less than 10,000, less than 100 respectively per c.c., then (preserving the same order), 7, 3, 5, and six *additional* samples would prove satisfactory.

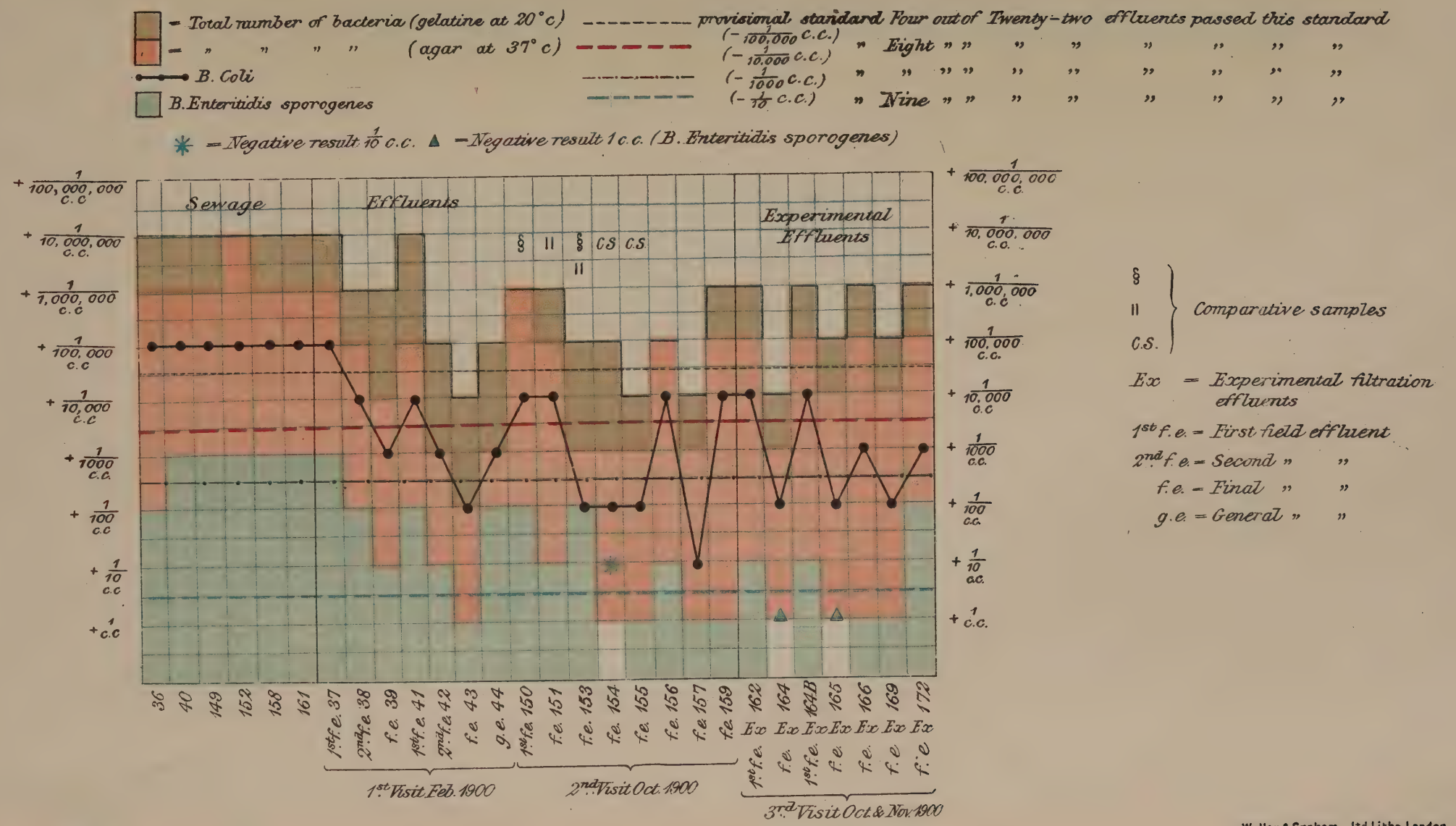
In the above summary the experimental and first and second field effluents are included. If these be excluded, then—

As regards (1), three out of 10 effluents
,, (2), six ,, 10 ,,
,, (3), five ,, 10 ,,
,, (4), five ,, 10 ,,

} "passed" the standards set up for these tests.

The results, as a whole, do not seem to show the impossibility of working land of the kind found at Beddington so as uniformly to yield

sewage & of effluents obtained from Beddington sewage farm.



3311. 9 02

Weller & Graham Ltd Litho. London.

an effluent which could pass the standards provisionally suggested by me. But it is evident that to ensure this result an increased area of land would be required.

3. *Results considered in relation to Mr. Kershaw's Notes.* (*See* Addendum D., page 79.)

Taking the B. enteritidis sporogenes test as a guide to the degree of purification effected by the land treatment, and dealing with the non-experimental effluents, it is to be noted that samples 43, 154, 155, 157, and 159 were undoubtedly good effluents. Of these Mr. Kershaw notes that sample 43 was a third field effluent, but it possessed a very slight sewage smell. 154, 155, 157, and 159 were also "third field or final effluents": the first two had a very faint sewage smell, but the two latter were free from any objectionable odour, and were classed as clear effluents. Taking the view that 100 or more spores of B. enteritidis sporogenes signifies a bad effluent, then samples 37, 38, 41, 44, 150, and 153 come under this category. Samples 37, 41 and 150 were "first field" effluents; samples 38 and 153 were "second field" effluents, and 44 was a general effluent. Most of them, according to Mr. Kershaw's notes, had a cloudy appearance and a sewage smell, and he further adds that samples 37 and 38 (also 39) were affected by snow and frost. As regards the nine final effluents (39, 43, 151, 153, 154, 155, 156, 157, and 159), five (about one-half) passed the "enteritidis" standard, and three additional samples were, on the basis of this test, fairly satisfactory.

As regards the experimental filtration effluents (162, 164, 164b, 165, 166, 169, 172), judged by the B. enteritidis sporogenes test, two were very good (164 and 165); two satisfactory (166 and 169); two fairly satisfactory (162 and 164b), and the remaining one (172) impure. This last sample was collected, according to Mr. Kershaw's notes, during the period when the flow of sewage was greatly increased. If sample 161, collected at this period, be taken as representing a fair sample of the kind of sewage applied to the land during the experiment (it contained 1,000 spores per c.c. of B. enteritidis sporogenes), the reduction in the number of spores effected by the experimental filtration treatment is worth noting. Thus, two samples (164, 165 final effluents) contained no spores of this anäerobe in 1 c.c.; two (166, 169 final experimental effluents) at least 1 but less than 10; two (162, 164b 1st field effluents) at least 10 but less than 100, and one effluent (172 final experimental effluent) at least 100 but less than 1,000 per c.c. This last sample was collected during the period when the land was being purposely over sewaged. The description of the experiment will be found in Mr. Kershaw's notes (Addendum D.), and it does not seem necessary here to repeat his summary of the facts.

Experiments of this kind present great practical difficulties, and it is impossible, unless they are carried out during a prolonged period, to draw, from a bacteriological point of view, from them any conclusion of real value. The only interpretation that can safely be put on the bacteriological results is that land of the kind available at Beddington can purify, to a reasonable extent, relatively large volumes of sewage.

4. *Results considered in relation to tests other than the B. enteritidis sporogenes test.*

So far the results have been chiefly considered as regards B. enteritidis sporogenes. With regard to the other tests, the following notes are of interest:—

Total Number of Bacteria, per c.c.

—	Gelatine at 20° C.	Agar at 37° C.	Ratio.
Sewage - - - - - - - -	29,000,000	5,315,000	5·4 : 1
Effluents (inclusive of the experimental and first and second field effluents).	2,972,509 [89% reduction.]	321,600 [93% reduction.]	9·2 : 1
Effluents (exclusive of the experimental and first and second field effluents).	1,413,200 [95% reduction.]	112,240 [97% reduction.]	12 : 1

The actual number of microbes remaining in the effluents is too great to allow of too much stress being laid on the marked percentage purification, in the effluents, effected by the land treatment. But the alteration in the ratio (from 5·4 : 1 to 9·2 : 1) of (*a*) total microbes (gelatine at 20° C.) to (*b*) bacteria growing at blood-heat (agar at 37° C.) should probably be regarded as a satisfactory feature of the bacteriological analyses. The averages, however, are far in excess of the standards suggested, viz., less than 100,000 (gelatine at 20° C.), and less than 10,000 (agar at 37° C.) microbes per c.c.

The *B. coli* results were not of a discouraging nature, since, although the as regards sewage contained at least 100,000 B. coli per c.c., eight out of the 22 effluents contained less than 1,000, and five additional samples less than 10,000. Moreover, if the first and second field and the experimental effluents be excluded, one-half of the effluents proved satisfactory.

In the table and diagram illustrating Appendix III. (page 196), the results as regards the "gas" and B. enteritidis sporogenes tests of the examination of effluents from various sewage farms are brought into comparison. Of 10 samples obtained from Beddington sewage farm, four for each test respectively passed the standard suggested, viz., gave a negative result, with $\frac{1}{10}$ c.c.

In Addendum A are given the results of the examination by means of simple tests of samples obtained from Beddington sewage farm. They will be dealt with in another section of the report.

As regards the *indol test* (indol in broth cultures, five days' at 37° C.), the following results were obtained :—

Sewage { Sample 36 + ·0001 c.c.
Samples 40, 149, 152, 158, 161 + ·00001 c.c.

Effluents { Samples 37, 150, 164 b. + ·00001 c.c.
„ 38, 39, 41, 162, 166, 172 + ·0001 c,c.
„ 42, 44, 151, 153, 156, 159, 165, 169 + ·001 c.c.
„ 43, 154, 164 + ·01 c.c.
„ 155, 157 + ·1 c.c.

It is to be noted that only five out the 22 effluents passed the standard suggested, as regards this test, namely, a negative result with ·001 c.c. Excluding, however, the experimental and first and second field effluents, 4 out of 10 effluents were satisfactory, and 9 out of 10 effluents either "passed" or came within reasonable distance of passing the above standard.

5. *Results of the bacteriological examination of additional samples of river water and mixed river water and effluent.*

The results of these examinations of the samples are shown in Table 9.

TABLE 9.—Showing the results of the bacteriological examination of samples of river water and effluent obtained from Beddington sewage farm.

Description of the Sample.	Total number of bacteria per c.c.		Number of B. coli (or closely allied forms) per c.c.	Number of Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in milk cultures) per c.c.
	Gelatine at 20° c.	Agar at 37° C.		
44 General effluent - - - 26th Feb. 1900.	169 000	7,400	1,000 not 10,000 [Indol + ·001 c.c.]	+ ·01 – ·001 c.c. At least 100 but less than 1,000.
45 River water (Wandle) above (340 yards) effluent outfalls. 26th Nov. 1900.	72,000	2,680	10 not 100 [Indol + ·1 c.c.]	+ 10 c.c. – 1 c.c. None in 1 c.c.
46 River water + effluent. 26th Feb. 1900. 130 yards below 44. Ratio of effluent to river water about 1 : 12,	500,000	10,900	1,000 not 10,000 [Indol + ·001 c.c.]	+ ·1 – ·01 c.c. At least 10 but less than 100.
47 Same lower down, 26th Feb. 1900. 230 yards below 46.	420,000	11,200	100 not 1,000 [Indol + ·01 c.c.]	+ 1 c.c. – ·1 c c. At least 1, but less than 10.

It is to be noted that the river water, 130 (sample 46) and 360 (sample 47) yards below the effluent outfalls, contained not only more bacteria than the river above the outfalls (sample 45), but more also than the general effluent (sample 44) previous to its admixture with river water. As regards both B. coli and the indol test, the results were the same as regards samples 44 (effluent alone) and 46 (mixed river water and effluent). But sample 47 (mixed river water and effluent, lower down) showed a tenfold decrease. Sample 45 (river water above effluent outfalls) contained one-tenth of the number of B. coli and indol producing bacteria present in sample 47. The river water above the outfalls (45) contained no spores of B. enteritidis sporogenes in 1 c.c. The effluent (44), the mixed river water and effluent (46), and the same lower down (47) contained respectively, per c.c., 100, 10, and 1 spores of this anäerobe.

In general terms, it may be said that the results seem to point to a considerable multiplication of bacteria in the river water as the result of the effluent discharging into it. The number of B. coli (relative to the dilution) would also appear to have increased at first, and 360 yards below the outfalls in relation to the dilution the numbers were not diminished.

B. enteritidis sporogenes in relation to the dilution was reduced in numbers in sample 47, but not in sample 46. Too much stress, from the bacteriological point of view, must, however, not be laid on these isolated observations. The river Wandle was, of course, not fit for drinking purposes above the effluent outfalls (sample 45), and 360 yards below the effluent outfalls it became roughly 10 times more impure.

6. *General Conclusions.**

Considered from the bacteriological point of view, none of the effluents were in a fit state to be turned into a drinking-water stream. The majority of the effluents, if the first and second field and experimental effluents be included, failed to pass the provisional standards suggested for effluents which are to be turned into non-drinking water streams. Excluding the above-mentioned effluents, about half the effluents were satisfactory. The average results were by no means so unsatisfactory as to indicate the impracticability of working land of the kind available at Beddington, so as uniformly to yield a reasonably good effluent. The fact that some of the effluents yielded such good results leads to the belief that, dealing with the same volume of sewage, the acquisition of a somewhat larger area of land might result in the production of effluents of a uniformly satisfactory character. Possibly, if the farm, instead of dealing with the total bulk of storm water, dealt only with the same proportion of storm water relative to dry-weather flow as is dealt with on many sewage farms, the results would be much more satisfactory.

It ought to be remembered that a large access of storm water not only at the time of its introduction affects injuriously the working of a sewage farm, but may also so disturb the equilibrium of the biological conditions, which make for purification of the sewage, as to exercise a more lasting prejudicial effect.

Addendum A.—*Results of the examination by means of simple tests of samples obtained from Beddington sewage farm.* (*Special Comparative Series of Experiments.*)

Five samples of sewage and 15 samples of effluent were examined by (1) the "gas" test, (2) B. enteritidis sporogenes, and (3) neutral red-broth tests.

The results are shown in Table 10 and Diagram 6.

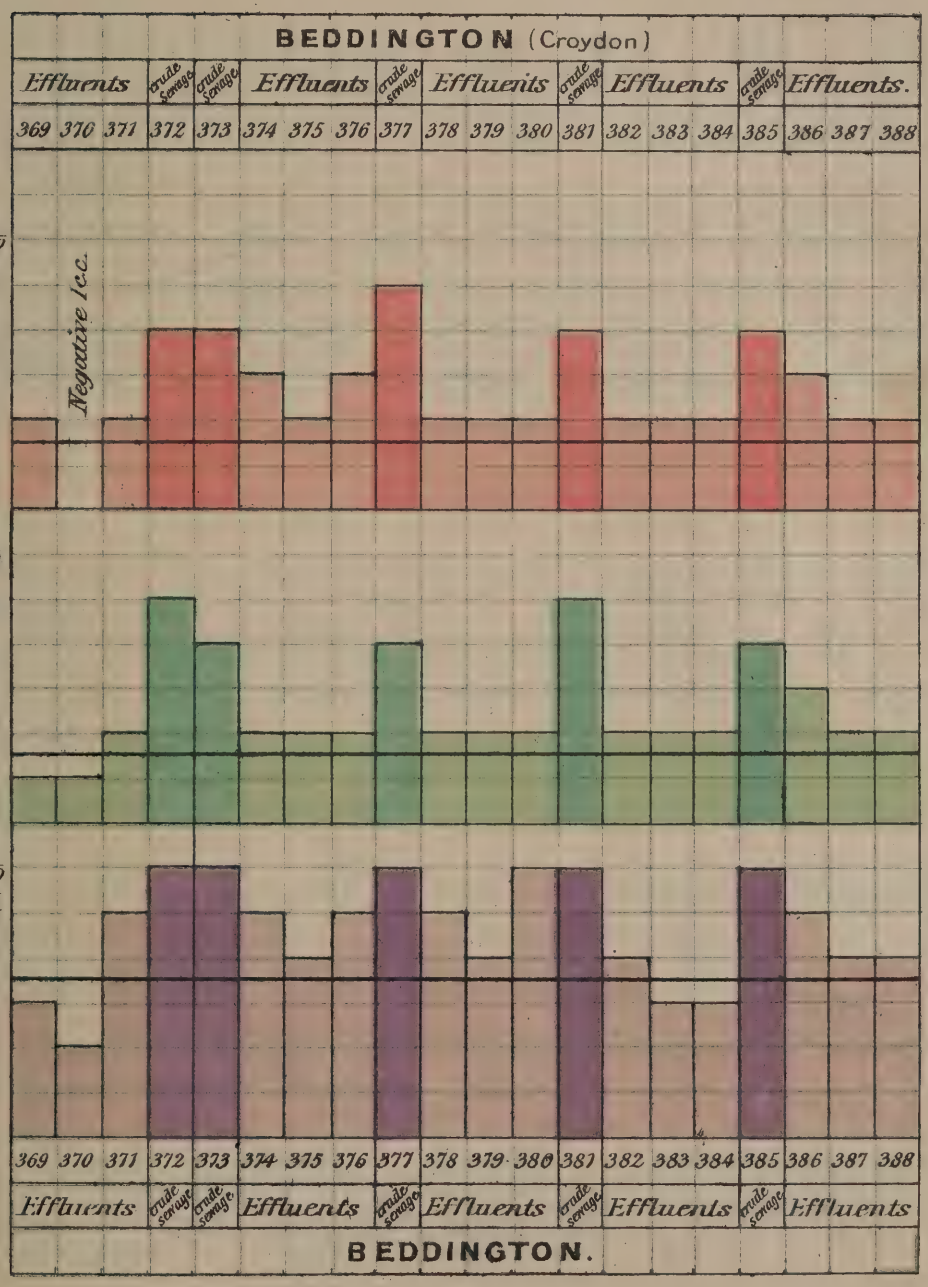
* For statistical information, see tabular statement at the beginning of this report, Section IV.

TABLE 10.—Showing as regards the (a) "Gas," (b) B. enteritidis sporogenes, and (c) Neutral red broth tests, the results of the bacteriological examination of five samples of sewage and fifteen samples of effluent obtained from Beddington (Croydon) Sewage Farm.

(The double line in each case refers to a provisional standard (non-drinking water streams). The sign + occurring on the right hand side of this line means that the effluent is condemned on the basis of this standard.)

Description of Sample.	"Gas" in gelatine "shake" culture (24 hours at 20° C.)						Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures).						Neutral red broth test (24 hours at 37° C. Greenish yellow fluorescence = positive result. No change in colour = negative result.						Sewage Farm.
	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	
369. General effluent (12.30 p.m., 7th October 1901, air 50° F., sample 50° F.)		+	−				+	−							+	−			
370. Final effluent off rye grass (2 p.m., 7th October 1901, air 51° F., sample 50° F.)	−						+	−						+	−				
371. Final effluent from rye grass (1.30 p.m., 7th October 1901, air 51° F., sample 51° F.)		+	−					+	−								+		
372. *Crude Sewage* (2 p.m., 7th October 1901, air 50° F., sample 57° F.)				+	−						+							+	
373. *Crude sewage*, dilute from rain 11.45 a.m., 8th October 1901, air 56° F., sample 58° F.)				+	−					+	−							+	
374. Final effluent off rye grass (12 noon, 8th October 1901, air 56° F., sample 52° F.)			+	−				+	−								+		
375. Final effluent off rye grass (12.15 p.m., 8th October 1901, air 57° F., sample 52° F.)		+	−					+	−							+	−		
376. General effluent (12.30 p.m., 8th October 1901, air 56° F., sample 53° F.)			+	−				+	−								+		
377. *Crude Sewage* (10.30 a.m., 9th October 1901, air 53° F., sample 56° F.)					+					+	−							+	
378. Final effluent off rye grass (11 a.m., 9th October 1901, air 52° F., sample 56° F.)		+	−					+	−								+		Beddington. (Croydon.)
379. Final effluent off rye grass (11.30 a.m., 9th October 1901, air 52° F., sample 56° F.)		+	−					+	−							+	−		
380. General effluent (12 p.m., 9th October 1901, air 52° F., sample 56° F.)		+	−					+	−									+	
381. Norbury.—*Crude Sewage* (10.45 a.m., 10th October 1901, air 54° F., sample 58° F.)				+	−						+							+	
382. Final effluent from rye grass (11 a.m., 10th October 1901, air 58° F., sample 58° F.)		+	−					+	−							+	−		
383. Final effluent (rye grass) (11.30 a.m., 10th October 1901, air 54° F., sample 56° F.)		+	−					+	−						+	−			
384. General effluent (12 noon, 10th October 1901, air 53° F., sample 56° F.)		+	−					+	−						+	−			
385. *Crude Sewage* (3 p.m., 11th October 1901, air 56° F., sample 58° F.)				+	−					+	−							+	
386. General effluent (2 p.m., 11th October 1901, air 58° F., sample 55° F.)			+	−					+	−							+	−	
387. Final effluent from rye grass (2.15 p.m., 11th October 1901, air 56° F., sample 54° F.)		+	−					+	−							+	−		
388. Final effluent off rye grass (2.30 p.m., 11th October 1901, air 56° F., sample 56° F.)		+	−					+	−							+	−		

Diagram 6 showing, as regards the (a) "gas"; (b) B enteritidis sporogenes; & (c) neutral red broth tests, the results of the bacteriological examination of five samples of sewage & fifteen samples of effluent obtained from Beddington sewage farm



+ equals Kleins "Enteritidis change" in anerobic milk broth cultures in 48 hrs. at 37°c.

+ equals "gas" in gelatine "shake" cultures in 24 hrs. at 20°c.

+ equals greenish yellow fluorescence in neutral red broth cultures in 24 hrs at 37°c.

The horizontal blank line in each case refers to a provisional standard.

Weller & Graham Ltd Litho London.

As regards (1), only one sample of effluent "passed," but no less than 11 additional samples came within measurable distance of passing the standard suggested. As regards (2), only two samples of effluent "passed," but no less than 12 additional samples came within measurable distance of passing the standard suggested. As regards (3), four samples "passed," and five additional samples came near passing the standard suggested.

The results are not altogether satisfactory; but it is to be noted that the majority of these effluents either passed, or nearly passed, the standards laid down for the respective tests; so that it cannot with justice be said that land of the kind available at Beddington could not possibly be worked so as uniformly to yield an effluent which would pass reasonable biological standards.

From Mr. Kershaw's notes, it appears that samples 369, 376, 380, 384, and 386 were general effluents, and samples 370, 371, 374, 375, 378, 379 382, 383, 387, 388, final effluents. Further, samples (382 and 387), (383 and 388), and (374, 378, and 379) were comparative (*i.e.*, drawn from the same areas of land respectively).

Addendum B.—*Comparative records as regards* (a) *the "gas" test and* (b) *B. enteritidis sporogenes tests of samples obtained from Beddington as well as other sewage farms.*

These results are shown in the Table and Diagram illustrating Appendix III. (page 196), and they include all the samples (from other sewage farms as well as Beddington) which were examined by both of these tests. These records are additional to the special series already described in Addendum A, and they deal with 194 samples, 13 of which were obtained from Beddington sewage farm. Four out of 10 (8, excluding 1st and 2nd field effluents) effluents passed respectively each of these tests.

Addendum C.—*Additional bacteriological notes.*

Streptococci :—

Streptococcus 14 (*see* Plate II., Fig. 3) was isolated from $\frac{1}{1000}$ c.c. of effluent 150. (Surface agar plate cultures at 37° C.). Microscopic examination revealed chains of medium length, and the organism stained well by Gram's method. In agar plate cultures the colonies were minute, slow growing, and transparent looking. In broth cultures, there was some diffuse cloudiness developed, and on gently shaking the tube, stringy growths were seen floating throughout the medium. In litmus milk cultures, there was acid formation but no clotting. The streptococcus was non-pathogenic to mice.

An unsuccessful attempt was made to isolate streptococci from ·01 c.c. (surface agar plate cultures at 37° C.) of effluent 47 (mixed river water and effluent, 360 yards below effluent outfalls). But from ·01 c.c. of effluent 46 (mixed river water and effluent, 130 yards below effluent outfalls), a microbe (Microbe 12), was isolated which was initially thought to be a streptococcus, although eventually it was classed as a (?) staphylococcus. The following is a brief description of this microbe :—

Microbe 12.—Isolated from ·01 c.c. of effluent 46 (surface agar plate cultures at 37° C.).

Morphology.—Cocci arranged chiefly in masses, but difficult to say whether or not the masses were composed of short chains of cocci.

Gelatine streak cultures (20° C.).—Appearance on the whole characteristic of a streptococcus, the colonies being fairly small and transparent looking. Later, the colonies became somewhat more opaque and acquired (?) a faintly yellowish tint. No liquefaction occurred within one month

Broth cultures (37° C.).—Nearly transparent but slightly granular cloudiness developed. At the foot of the tube, a white deposit of a decidedly granular character collected.

Litmus milk cultures (37° C.).—Practically no visible change apparent even after 10 days' incubation.

An unsuccessful attempt was made to isolate streptococci from $\frac{1}{1000}$ c.c. of effluent 151 (surface agar plate cultures). Both in this sample and also in sample 150, while searching for streptococci, vibrios were isolated. These vibrios all seemed to belong to the same species: they were stained with difficulty, gave no indol in broth cultures, produced alkali in milk cultures, and did not liquefy gelatine.

No streptococci could be found in ·0001 or ·001 c.c. of effluent 154.

Animal experiments:—Two guinea-pigs were inoculated subcutaneously, the one with 1 c.c. and the other with 4 c.c. of final effluent 154. They were hardly, if at all affected by the inoculation, and both recovered completely.

From 1 c.c. of sample 46 (mixed river water and effluent) a microbe indistinguishable from B. pyocyaneus was isolated; 1 c.c. of a broth culture injected subcutaneously into a guinea-pig produced a big swelling. The animal died, but not until the fifth day; this seems to show that the strain was not very virulent, as B. pyocyaneus thus injected usually kills a guinea-pig in from 24–48 hours.

From $\frac{1}{10}$ c.c. sample 47 (mixed river water and effluent), a microbe (? B. putidus) was isolated. This microbe did not liquefy gelatine; it grew luxuriantly at blood heat on agar, and produced at this temperature well marked green fluorescence. It was not found to be pathogenic to guinea-pigs.

During the month of October 1901, a few additional samples were examined bacteriologically, as regards the number of bacteria and the B. coli and indol tests. The results obtained are shown in the following table:—

Description of the sample.	Number of bacteria per c.c.		Number of B. coli per c.c.	Indol test (indol in broth cultures, 5 days at 37° C.)
	Gelatine at 20° C.	Agar at 37° C.		
369. General effluent, 8th Oct. 1901.	34,000	5,400	Less than 1,000	Negative ·001 c.c.
372. Crude sewage, 8th October 1901.	29,600,000	7,760,000	At least 100,000	+ ·00001 c.c.
374. Final effluent, 9th Oct. 1901.	1,640,000	732,000	At least 1,000	+ ·001 c.c.
376. General effluent, 9th Oct. 1901.	7,760,000	1,728,000	At least 1,000	+ ·001 c.c.
	(369 passed the standard of less than 100,000 microbes per c.c.)	(369 passed the standard of less than 10,000 microbes per c.c.)	(369 passed the standard of less than 1,000 B. coli per c.c).	(369 passed the standard of less than 1,000 indol producing bacteria per c.c.)

Plate II.

Fig. 3.

Fig. 4.

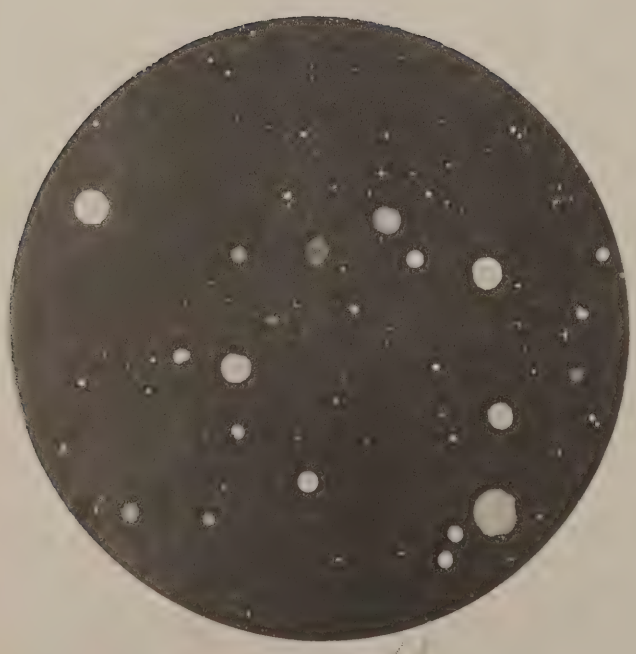


Fig. 5.

Fig. 6.

Plate II.

Figure 3.—Microscopic preparation from a broth culture of streptococcus 14. Isolated from $\frac{1}{1000}$ c.c. of Beddington effluent 150. Stained by Gram's method.

[Magnifying power, 1000.]

Figure 4.—Microscopic preparation from a broth culture of streptococcus 20. Isolated from $\frac{1}{10000}$ c.c. of Rugby effluent 230. Stained by Gram's method.

[Magnifying power, 1000.]

Figure 5.—Agar plate culture (37° C.), $\frac{1}{100}$ c.c. Rugby final effluent No. 229. Number of bacteria per c.c., 15,700.

[About natural size.]

Figure 6.—Lindfield final effluent No. 92, showing the result of the "gas" test ("gas" in gelatine shake cultures, 24 hours at 20° C.). The left tube represents 1 c.c. and the right tube $\frac{1}{10}$ c.c. of the sample. In both tubes the formation of gas is evident, but particularly in the left tube. A third tube (not represented in the photograph), inoculated with $\frac{1}{100}$ c.c., gave no "gas." A sample of sewage illustrated in a previous report, obtained from Lindfield, gave a positive result with $\frac{1}{1000}$ c.c.

Addendum D.—*Mr. Kershaw's abridged notes to accompany bacteriological data.*

CROYDON SEWAGE FARM.

(Beddington.)

Additional Notes on Samples.

Samples Nos. 37, 38, 39.—These samples were affected by the snow which fell two days previously, the fields irrigated being partially icebound, and covered with snow.

Sample No. 43.—This permanent pasture contained a great deal of water grass at the lower end.

Sample No. 45.—River Wandle water taken 340 yards above effluent outfalls; river slightly above norma height owing to rain, water slightly discoloured.

Sample No. 46.—River water and effluent taken 130 yards below sample No. 44. Ratio of effluent to river water about as 1 to 12. No sewage weed apparently.

Sample 47.—River water and effluent taken 230 yards below sample No. 46. No apparent signs of sewage weed. This sample could not be taken any lower down the river owing to the Carshalton effluent outfall.

Sample No. 150.—This first field had received too much sewage; the rye grass was in fair condition.

Sample No. 150A.—River water above effluent outfalls, very clear, river about normal.

Sample No. 154A.—River water above effluent outfalls; river very fine and clear.

Sample No. 155.—The giving way of a brick culvert near the railway, and consequent lifting of a sluice gat may possibly have effected this effluent injuriously.

Sample No. 155B.—River water and effluent taken 360 yards below effluent outfall; river clean and clear.

Sample No. 156A.—River water above effluent outfall; river very clear.

Sample No. 160A.—River water and effluent taken 360 yards below effluent outfall; river rather high.

EXPERIMENT.

Two fields were chosen for this experiment, one arable field of 16 acres, and one ryegrass field of 20 acres. The arable field was last sewaged on October 8th, 1900. The field was ploughed 8 inches deep all over a few days before the experiment began, and the soil seemed in a very clean condition. The last crop on this field was cabbages. The amounts of sewage put on were started at 25,000 gallons per acre for the 16 acres per 24 hours, and this amount was increased daily by 5,000 gallons. The field was partially under-drained, and the filtration effluent was taken on to the ryegrass field for second treatment. The sewage was turned on to the arable field on October 23rd, 1900, at 11 a.m. The sewage was kept running on continuously both day and night. There was a very small amount of subsoil water under both the arable and ryegrass fields, not sufficient to influence the experiment prejudicially.

The sewage turned on the first day was rather dilute and very soapy.

Sample No. 161.—25,000 gallons per acre for 16 acres going on. Sewage only fairly strong and very soapy.

Sample No. 162.—Owing to there being only one carrier available for the entire field, only about 4 acres were being irrigated, the land absorbing a large quantity.

Sample No. 163.—* 30,000 gallons per acre, 6 acres irrigated. The sewage from which the effluent was derived contained a large amount of black sewer scourings. Hardly any effluent going on to the second (ryegrass) field as yet.

Sample No. 163A.—Arable field effluent now going on ryegrass field. Sewage very black, and full of scourings.

Sample No. 163B.—This effluent, after leaving the arable field had, in passing over the ryegrass (1 acre), percolated through to the drains, the samples being drawn from a manhole.

Sample No. 163C.—Sewage normal.

Sample No. 163D.—Sewage about normal.

Sample No. 164B.—Sewage very dilute (from rain) and soapy. Samples 164B and 165 were taken when the sewage was going on to the arable field at the rate of about 83,000 gallons per 24 hours, or less than the usual dose the land receives ordinarily. The sewaging in the experiment had, however, been continuous, no rest being given to the fields.

Sample No. 166.—Sewage rather strong.

Sample No. 166A.—Taken about 360 yards below effluent outfall.

Sample No. 167A.—Sewage strong.

Sample No. 168.—Sewage soapy.

Sample No. 169.—This sample was a surface effluent from the ryegrass, taken at foot of field.

After these last samples had been drawn, the sewage run on the arable land was kept at a constant flow, and then increased on 8th November to about 3,000,000 gallons per 16 acres per 24 hours, and kept at that flow until Samples Nos. 172 and 173 were taken. The fields which had been sewaged during the experiment were again sewaged after a rest of 10 days, and had then recovered from the effects of the previous irrigation.

---

*This is at the rate of 30,000 gallons per acre for 16 acres, or 480,000 gallons in all, but only about 6 acres were actually receiving this quantity.

CROYDON SEWAGE FARM (BEDDINGTON).

(Domestic Sewage.)

Number of Sample.	Number of times the sewage is passed through or over the soil.	Area of plot or plots sewaged at the time of drawing Sample.	Length of time those plots had been sewaged previously to drawing Sample.	Nature of crops grown on plots.	Remarks.
		Acres.	Days.		
37	Once	21·25	*3	Ryegrass - - -	Only fairly clear.
38	Twice	16·50	3	,, - - -	,, ,, ,,
39	3 times	7·50	3	Permanent pasture -	Slight suspended matter.
41	Once	12·30 13·70	2	Ryegrass - - -	Cloudy effluent.
42	Twice	16·50	2	,, - - -	Fairly clear effluent.
43	3 times	7·50	2	Permanent pasture -	Very slight sewage smell.
150	Once	18·50	3	Ryegrass - - -	Effluent cloudy, sewage smell.
151	Twice	8·80	3	Permanent pasture -	Fairly clear, very slight sewage smell.
153	,,	18·50 8·80	4	Ryegrass and permanent pasture.	Very slight sewage smell, opalescent.
154	3 times	13·60 16·50 7·50	1	Ryegrass and permanent pasture.	Very slight sewage smell, opalescent.
155	,,	13·60 16·50 7·50	2	Ryegrass and permanent pasture.	Fairly clear, very faint sewage smell.
155a	,,	8·75 18·75 17·0	1	Arable and ryegrass; permanent pasture.	No smell, clear.
156	Twice	21·25 16·50	3	Ryegrass - - -	Clear effluent.
157	3 times	20·0 18·75 17·0	1	Arable and ryegrass; permanent pasture.	No smell and very clear, very little suspended matter.
159	,,	13·60 18·75 17·0	2	Arable and ryegrass; permanent pasture.	No smell.
160	,,	13·60 18·75 17·0	3	Arable and ryegrass; permanent pasture.	No smell, some suspended matter.
162	Once	4·0	1	Arable (freshly ploughed)	Filtration effluent.
163	,,	6·0	2	,, ,, ,,	,, ,,
163a	,,	8·0	3	,, ,, ,,	,, ,,
163b	Twice	8·0 & 1·0	3	,, and ryegrass -	Filtration effluent, very clear, no smell.
163c	,,	9·0 & 1·5	4	,, ,, -	Filtration effluent, very clear, no smell.
163d	Once	11·0	6	,, only - - -	Filtration effluent, very clear, no smell.
164	Twice	11·0 & 2·0	6	,, and ryegrass -	Filtration effluent, very clear, no smell.
164b	Once	12·0	8	,, only - - -	Filtration effluent.
165	Twice	12·0 & 2·0	8	,, ,, - - -	,, ,,
166	,,	13·0 & 2·5	10	,, ,, - - -	,, ,,
167a	Once	13·5	11	,, ,, - - -	,, ,,
167	Twice	13·5 & 2·10	11	,, ,, - - -	,, ,,
168	,,	15· & 2·25	13	,, ,, - - -	,, ,,
169a	Once	15·0	14	,, ,, - - -	Filtration effluent, strong sewage smell, turbid.
169	Twice	15 & 2·25	14	,, ,, - - -	Filtration and surface effluent.
172	,,	16·0 & 20·0	17	,, ,, - - -	Filtration and surface effluent, no smell.
173	,,	16·0 & 20·0	18	,, ,, - - -	Filtration and surface effluent, no smell.
369	—	—	—	—	General effluent.
370	3 times	11·25 & 10·0 & 17·0	1	Ryegrass.	
371	,,	11·25 & 10 & 7·5	1	,,	
374	Twice	13·50 & 17·0	2	,,	
376	—	—	—	—	,, ,,
378	Twice	13·50 & 17·0	3	Ryegrass.	
379	,,	13·50 & 17·0	3	,,	
380	—	—	—	—	,, ,,
382	3 times	7·0 10 & 20·25	1	Ryegrass.	
383	,,	7·0 10 & 7·5	4	,,	
384	—	—	—	—	,, ,,
386	—	—	—	—	,, ,,
387	3 times	7·0 10 & 20·25	2	Ryegrass.	
388	,,	7, 10 & 7·5	5	,,	

* The sewage is run on continuously, both day and night.

(DOMESTIC SEWAGE).

Number of Sample.	Date of drawing Sample.	Time of day.	Rainfall day previous to drawing Sample.	Rainfall day of drawing Sample.	Air temperature time of drawing Sample.	Temperature of Sample.	Maximum temperature during the 24 hours.	Minimum temperature during the 24 hours.	Humidity (9 a.m.)	Dissolved oxygen in Sample.	Brief description of Sample.	REMARKS.
	1900:		Inches.	Inches.	°C. °F.	°C. °F.	°C. °F.	°C. °F.				
36	12th February	12·15 p.m.	·00	·00	—	9·4 (49)	5·5 (42)	−8·3 (17)	—	—	Screened sewage.	Mean daily maximum temperature, 8·3 °C. (47°) F.
37	12 ,,	2·45 ,,	·00	·00	—	1·1 (34)	5·5 (42)	−8·3 (17)	—	—	First field effluent.	Mean daily minimum temperature, 0·1 °C. (32·2°) F.
38	12 ,,	4·30 ,,	·00	·00	—	4·4 (40)	5·5 (42)	−8·3 (17)	—	—	Second ,, ,,	Mean daily rainfall, ·109 in.
39	12 ,,	5·15 ,,	·00	·00	—	2·2 (36)	5·5 (42)	−8·3 (17)	—	—	Final effluent.	For the period 7th February to 2nd March, 1900.
30a	15 ,,	12·30 ,,	·18	·46	—	1·1 (34)	7·7 (46)	1·6 (35)	—	—	§General ,,	*Note.*—Samples which may have been affected by rainfall are underlined.
40	20 ,,	11·45 a m.	·32	·00	—	10·0 (50)	13·8 (57)	−1·1 (30)	—	—	Screened sewage.	
41	20 ,,	1·15 p.m.	·32	·00	—	8·3 (47)	13·8 (57)	−1·1 (30)	—	—	First field effluent.	§By "general" effluent is meant a mixture of two or more finally-treated effluents on leaving the farm.
42	20 ,,	2·50 ,,	·32	·00	—	7·7 (46)	13·8 (57)	−1·1 (30)	—	—	Second ,, ,,	
43	20 ,,	4 ,,	·32	·00	—	7·2 (45)	13·8 (57)	−1·1 (30)	—	—	Final ,, ,,	
44	26 ,,	4·35 ,,	·05	·25	—	13·3 (56)	16·1 (61)	7·7 (46)	—	—	General effluent.	
45	26 ,,	4·15 ,,	·05	·25	—	12·2 (54)	16·1 (61)	7·7 (46)	—	—	River water.	
46	26 ,,	5·5 ,,	·05	·25	—	13·3 (56)	16·1 (61)	7·7 (46)	—	—	,, ,, and effluent.	
47	26 ,,	5·30 ,,	·05	·25	—	11·1 (52)	16·1 (61)	7·7 (46)	—	—	,, ,, ,, ,,	
	1900:									C.C.		
149	3rd October	11·45 a.m.	·00	·00	12·7 (55)	15·0 (59)	15·5 (60)	5·0 (41)	—	Less than 1 c.c.	Screened and settled sewage.	Mean daily maximum temperature, 16·1° C. (61°) F.
150	3 ,,	2 p.m.	·00	·00	16·1 (61)	13·8 (57)	15·5 (60)	5·0 (41)	—	—	First field effluent.	Mean daily minimum temperature, 4·4 °C. (40°) F.
150a	3 ,,	2.30 p.m.	·00	·00	12·2 (54)	11·6 (53)	15·5 (60)	5·0 (41)	—	—	River water.	Mean daily rainfall, ·03 in.
151	3 ,,	3·30 p.m.	·00	·00	13·8 (57)	12·7 (55)	15·5 (60)	5·0 (41)	—	—	Final effluent.	For the period 3rd October to 21st October, 1900.
152	8 ,,	11 a.m.	·00	·00	18·3 (65)	14·4 (58)	22·2 (72)	5·5 (42)	—	—	Screened and settled sewage.	
153	8 ,,	2·30 p.m.	·00	·00	20·5 (69)	15·0 (59)	22·2 (72)	5·5 (42)	—	5·0	Final effluent.	
154	9 ,,	2· ,,	·00	·00	18·3 (65)	16·6 (62)	23·3 (74)	10·5 (51)	—	3·50	,, ,,	

CROYDON SEWAGE FARM (BEDDINGTON) (Domestic Sewage)—*continued.*

Number of Sample.	Date of drawing Sample.	Time of day.	Rainfall day previous to drawing Sample.	Rainfall day of drawing Sample.	Air temperature time of drawing Sample.		Temperature of Sample.		Maximum temperature during the 24 hours.		Minimum temperature during the 24 hours.		Humidity (9 a.m.)	Dissolved oxygen in Sample.	Brief description of Sample.	REMARKS.
	1900:		Inches.		°C.	°F.	°C.	°F.	°C.	°F.	°C.	°F.				
154a	9 October	2·30 p.m.	·00	·00	17·7	(64)	14·4	(58)	23·3	(74)	10·5	(51)	—	8·0	River water.	
155	10 ,,	1·45 ,,	·00	·00	14·4	(58)	14·4	(58)	22·2	(72)	11·6	(53)	—	1·50	Final effluent.	
155a	11 ,,	1·15 ,,	·00	·00	11·1	(52)	13·3	(56)	14·4	(58)	−0·5	(31)	—	7·0	,, ,,	
155b	11 ,,	1·35 ,,	·00	·00	13·3	(56)	10·5	(51)	14·4	(58)	−0·5	(31)	—	7·0	River water and effluent.	
156	15 ,,	2.45 ,,	.00	·025	10·0	(50)	10·0	(50)	12·2	(54)	0·0	(32)	—	4·50	Final effluent.	
156a	15 ,,	3.15 ,,	·00	·025	10·0	(50)	8·8	(48)	12·2	(54)	0·0	(32)	—	10·0	River water.	
157	16 ,,	12.45 ,,	·025	·00	10·5	(51)	10·0	(50)	12·7	(55)	−2·7	(27)	—	6·25	Final effluent.	
158	17 ,,	12 (noon)	·00	·015	17·7	(64)	15·5	(60)	18·3	(65)	7·7	(46)	—	—	Screened sewage.	
159	17 ,,	5 p.m.	·00	·015	13·3	(56)	12·2	(54)	18·3	(65)	7·7	(46)	—	2·0	Final effluent.	
160a	18 ,,	2.45 p.m.	·015	·00	14·4	(58)	11·1	(52)	17·7	(60)	5 0	(41)	—	—	River water and effluent.	
160	18 ,,	2.30 ,,	·015	·00	14·4	(58)	12·2	(54)	17·7	(64)	5·0	(41)	—	2·0	Final effluent.	
	1900:								EXPERIMENT.							
161	24 October	12.15 ,,	·015	·00	15·0	(59)	14·4	(58)	15·0	(59)	3·8	(39)	—	—	Screened sewage.	
162	24 ,,	2.30 ,,	·015	·00	15·5	(60)	13·8	(57)	15·0	(59)	3·8	(39)	—	1·0	First effluent.	
163	25 ,,	12.30 ,,	·00	·045	13·3	(56)	13·3	(56)	15·5	(60)	11·6	(53)	—	0·50	,, ,,	
163a	26 ,,	12.15 ,,	·045	·21	7·2	(45)	13·8	(57)	13·8	(57)	5·0	(41)	—	—	,, ,,	Mean daily maximum temperature, 14·1 °C. (57·4°) F.
163b	26 ,,	12.45 ,,	·045	·21	7·2	(45)	11·6	(53)	13·8	(57)	5·0	(41)	—	—	Final effluent.	Mean daily minimum temperature, 6·8 °C. (44·4°) F.
163c	27 ,,	12.45 ,,	·21	·00	10·5	(51)	12·2	(54)	12·2	(54)	0·0	(32)	—	2·0	,, ,,	Mean daily rainfall, ·077 in.
163d	29 ,,	12 (noon)	·145	·030	12·7	(55)	13·3	(56)	12·7	(55)	8·3	(47)	—	—	First ,,	For the period 22nd October to 6th November 1900.
164	29 ,,	12.45 p.m.	·145	·030	12·2	(54)	11·6	(53)	12·7	(55)	8·3	(47)	—	2·25	Final ,,	
164a	31 ,,	11.30 a.m.	·55	·015	18·3	(65)	14·4	(58)	17·7	(64)	8·8	(48)		—	Screened sewage.	
164b	31 ,,	12.45 p.m.	·55	·015	18·8	(66)	12·7	(55)	17·7	(64)	8·8	(48)	—	—	First effluent.	

165	31 October	1 p.m.	·55	·015	18·8	(66)	11·6	(53)	17·7	(64)	8·8	(48)	—	2·0	Final effluent.	
166a	2 November	11.20 a.m.	·115	·09	14·4	(58)	11·6	(53)	16·1	(61)	9·4	(49)	—	6·0	River water and effluent.	
136	2 ,,	12.40 p.m.	·115	·09	14·4	(58)	12·2	(54)	16·1	(61)	9·4	(49)	—	—	Final effluent.	
167a	3 ,,	12.20 ,,	·09	·00	14·4	(58)	13·3	(56)	13·8	(57)	10·0	(50)	—	—	First ,,	
167	3 ,,	12.30 ,,	·09	·00	14·4	(58)	12·2	(54)	13·8	(57)	10·0	(50)	—	1·75	Final ,,	
168	5 ,,	12.50 ,,	·00	·015	14·4	(58)	12·2	(54)	13·8	(57)	9·4	(49)	—	1·0	,, ,,	
169a	6 ,,	12 noon	·015	·015	13·8	(57)	12·7	(55)	15·0	(59)	8·8	(48)	—	—	First ,,	
169	6 ,,	12.40 p.m.	·015	·015	13·3	(56)	12·7	(55)	15·0	(59)	8·8	(48)	—	4·0	Final ,,	
172	9 ,,	3·15 ,,	·24	·05	10·5	(51)	11·1	(52)	10·5	(51)	6·1	(43)	74	—	,, ,,	
173	10 ,,	1.45 ,,	·05	·00	10·5	(51)	8·3	(47)	11·6	(53)	– ·5	(31)	92	—	——	
							End of Experiment.									
369	1901: 7 October	12.30 p.m.	·18	·00	10·0	(50)	10·0	(50)	11·1	(52)	5·0	(41)	For the period 7th Oct. to 11th Oct. 1901. Mean daily maximum temperature, 13·4 °C. (56·2°) F. Mean daily minimum temperature, 6·2 °C. (43·2°) F. Mean daily rainfall, ·006 inch.		General effluent	Slight yellow colour.
370	7 ,,	2 ,,	·18	·00	10·5	(51)	10·0	(50)	11·1	(52)	5·0	(41)			Final ,,	Clear.
371	7 ,,	1.30 ,,	·18	·00	10·5	(51)	10·5	(51)	11·1	(52)	5·0	(41)			,, ,,	,,
372	7 ,,	2 ,,	·18	·00	10·5	(50)	13·8	(57)	11·1	(52)	5·0	(41)			Screened sewage	Dilute after rainfall.
373	8 ,,	11.45 a.m.	·00	·03	13·3	(56)	14·4	(58)	11·6	(53)	5·0	(41)			,, ,,	,, ,,
374	8 ,,	12 noon	·00	·03	13·3	(56)	11·1	(52)	11·6	(53)	5·0	(41)			Final effluent	Clear, no smell.
375	8 ,,	12.15 p.m.	·00	·03	13·8	(57)	11·1	(52)	11·6	(53)	5·0	(41)			,, ,,	,, ,,
376	8 ,,	12.30 ,,	·00	·03	13·3	(56)	11·6	(53)	11·6	(53)	5·0	(41)			General effluent	Fairly clear, no smell.
377	9 ,,	10.30 a.m.	·03	·00	11·6	(53)	14·4	(58)	15·0	(59)	8·8	(48)			Screened sewage	Rather weak.
378	9 ,,	11 ,,	·03	·00	11·1	(52)	13·3	(56)	15·0	(59)	8·8	(48)			Final effluent	Clear.
379	9 ,,	11.30 ,,	·03	·00	11·1	(52)	13·3	(56)	15·0	(59)	8·8	(48)			,, ,,	,,
380	9 ,,	12.10 p.m.	·03	·00	11·1	(52)	13·3	(56)	15·0	(59)	8·8	(48)			General effluent	Rather cloudy.
381	10 ,,	10.45 a.m.	·00	·00	12·2	(54)	14·4	(58)	15·5	(60)	3·8	(39)			Screened sewage	Normal.
382	10 ,,	11 ,,	·00	·00	14·4	(58)	14·4	(58)	15·5	(60)	3·8	(39)			Final effluent	Clear.
383	10 ,,	11.30 ,,	·00	·00	12·2	(54)	13·3	(56)	15·5	(60)	3·8	(39)			,, ,,	,,
384	10 ,,	12 noon	·00	·00	11·6	(53)	13·3	(56)	15·5	(60)	3·8	(39)			General effluent	Clearer than No. 380.
385	11 ,,	3 p.m.	·00	·00	13·3	(56)	14·4	(58)	13·8	(57)	8·3	(47)			Screened sewage	A normal sample.
386	11 ,,	2 ,,	·00	·00	14·4	(58)	12·7	(55)	13·8	(57)	8·3	(47)			General effluent	Clear, slight yellow colour.
387	11 ,,	2.15 ,,	·00	·00	13·3	(56)	12·2	(54)	13·8	(57)	8·3	(47)			Final effluent	Clear.
388	11 ,,	2.30 ,,	·00	·00	13·3	(56)	13·3	(56)	13·8	(57)	8·3	(47)			——	——

CROYDON SEWAGE FARM (BEDDINGTON).

(Domestic Sewage.)

* Comparative Samples, or Samples taken from the same plots of land.

1st Field Effluents.	2nd Field Effluents.	3rd Field or Final Effluents.	Remarks.
{(150) (153)}	{(151) (153)}	{(154) (155)}	* By comparative samples is meant samples drawn from the same areas of land, and the effluents in brackets are comparable with each other so far as the area of land sewaged is concerned.
	{(374) (378) (379)}	{(159) (160)}	
	{(172) (173)}	{(382) (387)}	
		{(383) (388)}	

Section V.

LEICESTER SEWAGE FARM.

1. Situation of farm.—Beaumont Leys, about two miles from Leicester.

2. Total acreage of farm.—1,699 acres.

3. Total irrigable area.—1,350 acres.

4. Average area irrigated at one time.—337 acres.

5. Population draining to farm.—197,000.

6. Population per acre irrigated.—146.

7. Gallons of sewage per head per day.—36·8.

8. Dry-weather flow of sewage per 24 hours.—7,250,000 gallons.

9. Gallons of sewage (exclusive of storm water) treated per acre per hours.—21,500 gallons $= (\frac{7250000}{337})$.

10. Gallons of sewage treated per acre per 24 hours, on the assumption that each acre of the irrigable area is under sewage all the time $= (\frac{7250000}{1350}) =$ 5,370 gallons.

11. Characters of the sewage.—Domestic, about three-quarters; trade effluent, nearly one-quarter.

12. Method of treatment.—Screening, settling tanks, surface irrigation, and filtration combined.

13. General characters of the soil and subsoil.—Stiff clayey soil overlying dense clay.

14. Separate or combined sewerage system.—Partially separate.

15. The final effluent is discharged into.—Anstey Brook, flowing into River Soar.

16. Number of years farm in operation before 1900.—Nine years.

A full description of Leicester sewage farm will be found in Mr. Kershaw's report (Part IV., Engineering and Practical Report). A few notes, however, may be very briefly here inserted, as follows :—

The soil is a stiff clay and cracks badly in hot weather. There is practically no subsoil water on the farm. The volume of trade refuse, well and subsoil water gaining access to the sewers is considerable. The town is chiefly on the water-closet system. The main storm water overflow comes into action when the combined volume of sewage and storm water exceeds twice the dry weather flow. The method of treatment is, generally speaking, to send the sewage, after rough screening and settlement, over one arable field and then over one or more pasture fields. Mr. Kershaw lays much stress in his report on the system of under-draining and the conformation of the land which allows of the effluents, if inadequately purified, being "picked up" and "re-treated." The total acreage of the farm is 1,699 acres, of which 1,350 acres are actually irrigated, the remaining 349 acres being used for grazing purposes when all the cattle cannot be turned on to the sewaged land. As regards the 1,350 actually irrigated, 902 acres are pasture land and 448 arable land. About 1,111 acres are cropped. Wheat, oats, roots, and mangold wurzels are grown, but ryegrass constitutes the principal crop.

The following is a summary of the several sections of the report in so far as it relates to Leicester sewage farm :—

1. Tabular statement and summary of the chief bacteriological results.

2. Diagram 7 illustrating the results shown in Table 11, with comments thereon.

3. Results considered in relation to Mr. Kershaw's notes.

4. Results in relation to tests other than the B. enteritidis sporogenes test.

5. Results of the examination of additional samples of subsoil water, brook water, and mixed brook water and effluent.

6. General conclusions.

Addendum A.—Results of the examination, by means of simple tests, of samples obtained from Leicester sewage farm (special comparative series of experiments).

Addendum B.—Additional notes.

Addendum C.—Mr. Kershaw's abridged notes to accompany bacteriological data.

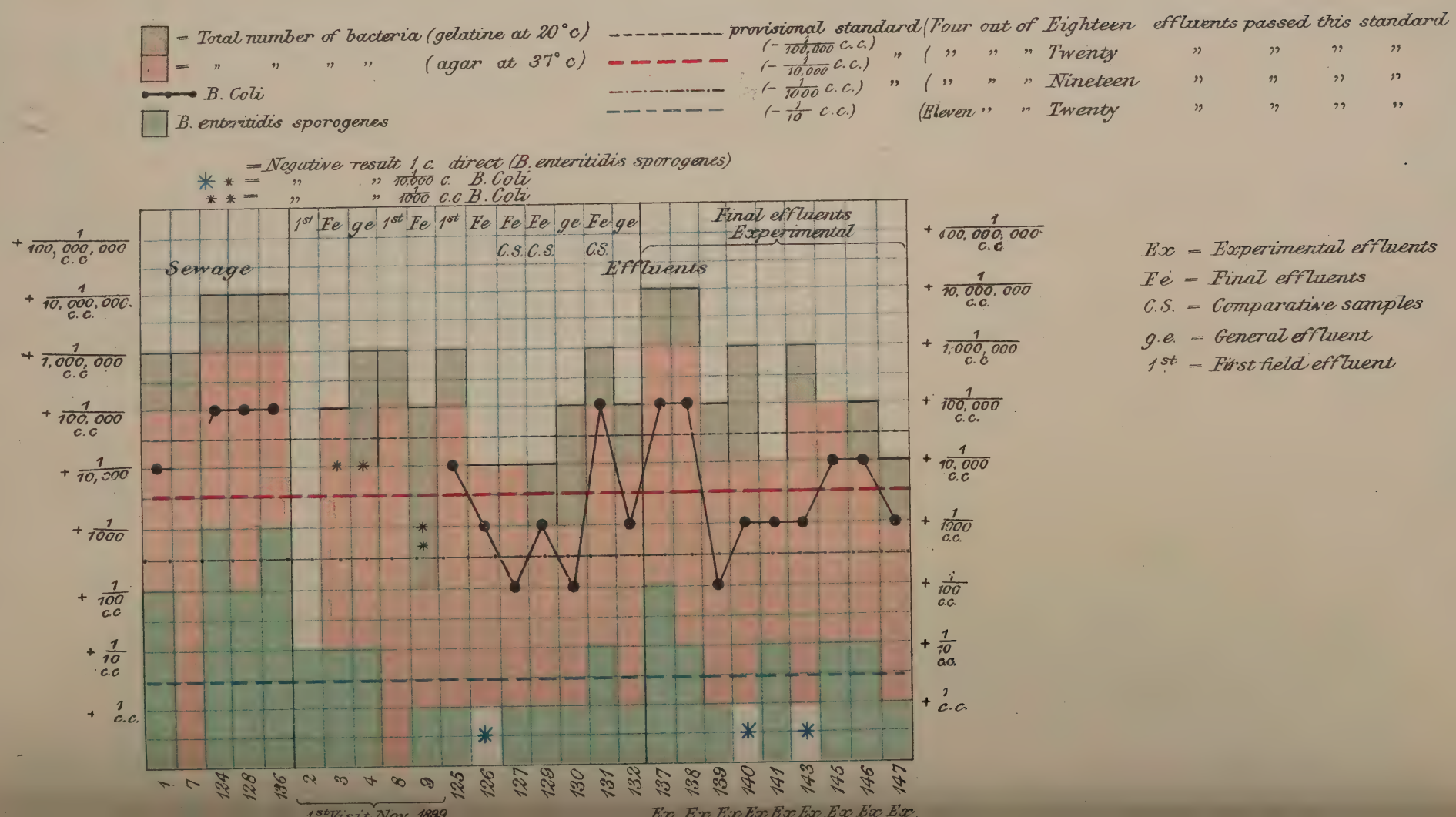
1. *Tabular statement and summary of the chief bacteriological results.*

The following table (Table 11) shows, as regards the total number of bacteria, B. coli, and spores of B. enteritidis sporogenes, the results of the bacteriological examination of five samples of sewage and 21 samples of effluent.

TABLE 11.—Showing as regards the total number of bacteria, B. coli, and spores of B. enteritidis sporogenes, the results of the bacteriological examination of sewage and effluents obtained from Leicester Sewage Farm.

Description of the Sample.	Total number of bacteria per c.c.		Number of B. coli (or closely allied forms) per c.c.	Number of Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in milk culture) per c.c.	
	Gelatine at 20° C.	Agar at 37° C.			
1.	2.	3.	4.	5.	
1 Settled sewage - - - 11.15 a.m., 8th Nov. 1899.	4,100,000	416,000	At least 30,000 -	+ ·01, – ·001 c.c. At least 100 but less than 1,000.	
7 Settled sewage - - - 12 (noon), 21st Nov. 1899.	5,200,000	720,000	—	———	
124 Settled sewage - - - 12.30 p.m., 21st Aug. 1900.	12,700,000	2,070,000	At least 100,000 -	+ ·001, – ·0001 c.c. At least 1,000 but less than 10,000.	
128 Settled sewage - - - 11.15 a.m., 27th Aug. 1900.	12,500,000	1,304,000	- ditto - -	+ ·01, – ·001 c.c. At least 100 but less than 1,000	
136 Settled sewage - - - 12 p.m., 10th Sept. 1900.	26,600,000	3,560,000	- ditto - -	+ ·001 c.c. At least 1,000.	
Averages - - -	12,220,000	1,614,000	[Ratio cols. 2 to 3 = 7·5 : 1.		
2 First field effluent - - 12.30 p.m., 8th Nov. 1899.	—	—	—	+ ·1 c.c. At least 10.	First visit, November 1899.
3 Final effluent - - - 3 p.m., 8th Nov. 1899.	460,000	350,000	Absent from $\frac{1}{10000}$ c.c.	+ ·1, – ·01 c.c. At least 10 but less than 100.	
4 General effluent - - - 3 p.m. 14th Nov. 1899.	1,040,000	59,000	- ditto - -	- ditto - ditto.	
8 First field effluent - - 1.30 p.m., 21st Nov. 1899.	1,890,000	286,000	—	———	
9 Final effluent - - - 2.45 p.m., 21st Nov. 1899.	500,000	300	Absent from $\frac{1}{1000}$ c.c.	+ 1, – ·1 c.c. At least 1 but less than 10.	
125 First field effluent - - 1.30 p.m., 21st Aug. 1900.	1,030,000	553,000	At least 10,000 but less than 100,000.	- ditto - ditto.	Second visit, August and September 1900.
126 Final effluent - - - 3.15 p.m., 21st Aug. 1900.	48,000	13,400	At least 1,000 but less than 10,000.	– 1 c.c. None in 1 c.c.	
127 Final effluent - - - 2 p.m., 22nd Aug. 1900.	73,000	31,300	At least 100 but less than 1,000.	+ 1, – ·1 c.c. At least 1 but less than 10.	
129 Final effluent - - - 2 p.m., 27th Aug. 1900.	43,000	4,700	At least 1,000 but less than 10,000.	- ditto - ditto.	
130 General effluent - - - 11.45 a.m., 29th Aug. 1900.	141,000	8,800	At least 100 but less than 1,000.	- ditto - ditto.	
131 Final effluent - - - 11.30 a.m., 30th Aug. 1900.	1,930,000	122,000	At least 100,000 -	+ ·1, – ·01 c.c. At least 10 but less than 100.	
132 General effluent - - - 11.45 a.m., 3rd Sept. 1900.	560,000	45,000	At least 1,000 but less than 10,000.	+ 1, – ·1 c.c. At least 1 but less than 10.	
Experimental effluents: 137 Final effluent - - - 1 p.m., 11th Sept. 1900.	22,560,000	1,264,000	At least 100,000 -	+ ·01 c.c. At least 100.	
138 Final effluent - - - 12 p.m., 12th Sept. 1900.	16,400,000	1,344,000	- ditto - -	+ ·1, – ·01 c.c. At least 10 but less than 100.	
139 Final effluent - - - 12 p.m., 17th Sept. 1900.	800,000	38,200	At least 100 but than 1,000.	+ 1, – ·1 c.c. At least 1 but less than 10.	
140 Final effluent - - - 12 p.m., 18th Sept. 1900.	1,110,000	43,000	At least 1,000 but less than 10,000.	+ 10 c.c., – 1 c.c. None in 1 c.c.	
141 Final effluent - - - 12 p.m., 19th Sept. 1900.	—	15,000	- ditto - -	+ ·1 c.c. At least 10.	
143 Final effluent - - - 12 p.m., 21st Sept. 1900.	1,820,000	712,000	- ditto - -	– 1 c.c. None in 1 c.c.	
145 Final effluent - - - 12 p.m., 24th Sept. 1900.	—	294,000	At least 10,000 but less than 100,000.	+ ·1, – ·01 c.c. At least 10 but less than 100.	
146 Final effluent - - - 12 p.m., 25th Sept. 1900.	171,000	23,500	- ditto - -	- ditto - ditto.	
147 Final effluent - - - 12 p.m., 26th Sept. 1900.	86,000	4,000	At least 1,000 but less than 10,000.	+ 1, – ·1 c.c. At least 1 but less than 10.	
Averages - - -	2,814,555 77% reduction.	260,550 83% reduction	[Ratio cols. 2 to 3 = 10·8 : 1.]		
Excluding the experimental effluents 137 to 147, but including the first field effluents, the averages are - - - -	701,363 94% reduction.	133,954 91% reduction.	[Ratio cols. 2 to 3 = 5·2 : 1.]		
Excluding the experimental and first field effluents, the averages are - - - - - -	532,777 95% reduction.	70,500 95% reduction.	[Ratio cols. 2 to 3 = 7·5 : 1]		

Diagram 7 shewing as regards (1) total number of bacteria, (2) B. Coli, (3) Spores of B. enteritidis sporogenes the results of the bacteriological examination of samples of sewage & of effluents obtained from Leicester sewage farm.



Brief Summary of the results shown in Table 11.

Sewage :—

Total number of bacteria (gelatine at 20°C.) :—Three samples contained over ten million bacteria per c.c., and two samples contained more than one but less than ten million microbes per c.c.

Total number of bacteria (agar at 37°C.) :—Three samples contained over one but less than ten million microbes in 1 c.c. Two samples contained more than 100,000, but less than 1,000,000 micro-organisms per c.c.

B. coli (and closely allied forms) :—One sample contained at least 30,000 per c.c. The other three samples contained at least 100,000 in 1 c.c.

Spores of B. enteritidis sporogenes :—Two samples gave a positive result with ·01 c.c. and a negative result with ·001 c.c. (at least 100 but less than 1,000). Two samples contained at least 1,000 per c.c.

Effluents :—

Total number of bacteria (gelatine at 20°C.) :—Four samples contained more than 10,000 but less than 100,000 ; six samples between 100,000 and one million. Six samples between one million and ten million, and two samples over ten million bacteria respectively per c.c.

Total number of bacteria (agar at 37°C.) :—One sample contained less than 1,000 ; three samples between 1,000 and 10,000 ; eight samples between 10,000 and 100,000 ; six samples between 100,000 and one million ; and two samples between one million and ten million bacteria respectively per c.c.

B. coli (and closely allied forms) :—Three samples contained at least 100 but less than 1,000. One sample absent from $\frac{1}{1000}$ c.c. Seven samples at least 1,000 but less than 10,000. Two samples, absent from $\frac{1}{10000}$ c.c. Three samples at least 10,000 but less than 100,000. Three samples at least 100,000 B. coli per c.c.

Spores of B. enteritidis sporogenes :—Three samples contained none in 1 c.c. Eight samples at least 1 but less than 10. Six samples at least 10 but less than 100. Two samples at least 10. One sample at least 100 per c.c.

2. *Diagram 7, illustrating the results shown in Table* 11, *with comments thereon.*

The results are shown in graphic form in Diagram 7.

By referring to the diagram, it will be seen that certain horizontal lines are drawn to indicate provisional standards (non-drinking water streams).

All samples, which, according to these standards, did not fulfil the following requirements would be tentatively condemned :—

(1.) Total number of bacteria (gelatine 20° C.). Less than 100,000).	per c.c.
(2.) Total number of bacteria (agar at 37° C.). Less than 10,000).	per c.c.
(3.) B. coli. Less than 1,000 - - - - - -	per c.c.
(4.) B. enteritidis sporogenes. Less than 10 - - -	per c.c.

As regards (1) 4 out of 18 (3 out of 11, excluding the experimental effluents, and 3 out of 9, excluding the first field effluents) effluents proved satisfactory.

As regards (2) 4 out of 20 (3 out of 11, excluding the experimental effluents, and 3 out of 9, excluding the first field effluents) effluents passed this standard.

As regards (3) 4 out of 19 (3 out of 10, excluding the experimental effluents, and 3 out of 9, excluding the first field effluents) effluents were satisfactory.

As regards (4) 11 out of 20 (7 out of 11, excluding the experimental effluents, and 6 out of 9, excluding the first field effluents) effluents passed this standard.

The variable character of the different effluents is striking, some were nearly as impure as raw sewage, others showed a high percentage degree of purification.

Admitting a certain parallelism between the results yielded by the different tests, it is found in practice that this seeming agreement is not uniformly maintained.

The B. enteritidis sporogenes test usually affords a useful means of estimating the degree of purification effected by land treatment. The results set forth in Table 11, show that the sewage contained from 100 (two samples) to 1,000 (two samples) spores of this anäerobe. As regards the effluents, including the experimental effluents, only one sample (137) gave a positive result with $\frac{1}{100}$ c.c. Eight effluents yielded a positive result with $\frac{1}{10}$ and eight with 1 c.c. Three samples even gave a negative result with 1 c.c. About one-half the effluents passed the standard of a negative result with $\frac{1}{10}$ c.c. These results are remarkably good in view of the clayey character of the soil on the sewage farm. But the effluents, as judged by other tests were much less satisfactory ; and a series obtained at a latter date (Addendum A) were, as regards the B. enteritidis sporogenes test, more impure. Of these later samples one-third passed the standard of a negative result with $\frac{1}{10}$ c.c.

The results in general do not suggest the possibility of land of the kind available at Leicester being worked so as uniformly to yield a really satisfactory effluent. But the fact that a few of the effluents were good and a number of them fairly pure leads to the belief that the acquisition of an additional area of land to treat the same volume of sewage as is now dealt with would produce an effluent which might satisfy reasonable standards.

3. *Results considered in relation to Mr. Kershaw's Notes.**

Leaving the experimental effluents out of consideration for the moment, it will be noted that no less than seven out of eleven samples, although in other respects they were usually found to be unsatisfactory, passed the standard suggested for the B. enteritidis sporogenes test. But it is difficult to say why the results were relatively better when judged by this test as compared with other tests. The results of the bacteriological examination of the crude sewage do not indicate that the presence of trade refuse modified the biological qualities of the sewage to any great extent. Nor from a study of Mr. Kershaw's careful notes does it seem possible always to explain satisfactorily the variable character of the different effluents as regards the bacteriological tests in general. But effluent 131 was very unsatisfactory, and Mr. Kershaw's note that the bullocks in the field had disturbed the soil possibly explains this. Further, the first field were certainly worse than the final and general effluents. Of course, it is hardly necessary to say that the first field effluents are submitted to further treatment before leaving the farm.

As regards the experimental effluents, reference should be made to Mr. Kershaw's notes (Addendum C), in which the progress of the experiment is described in detail. The object of the experiment was, if possible, to ascertain by daily increased doses of sewage, the limit of the purifying power of the soil. It is unnecessary to repeat here Mr. Kershaw's description of the experiment, as his notes on the subject are given in full in Addendum C. The bacteriological results may be summed up as follows:—

B. enteritidis sporogenes, 3 out of 9 samples - -	passed the standards set up for these tests.
Total number of bacteria (gelatine at 20° C.) 1 out of 7 samples - - - - - - - -	
Total number of bacteria (agar at 37° C.) 1 out of 9 samples - - - - - - - - -	
B. *coli* 1 out of 9 samples - - - - - -	

It will thus be seen that the results in general were of an unsatisfactory nature. The first two effluents were very unsatisfactory ; later on in the experiment the effluents improved in biological quality ; but the results yielded by the different tests varied so greatly as to render it impossible to come to any but the general conclusion, namely, that the results throughout were unsatisfactory. Nevertheless, the percentage purification effected by the process was considerable. Briefly, it may be said that under the conditions of the experiment the land failed to purify the sewage to a satisfactory extent. To obtain definite results from experiments of this kind the investigation

* Addendum C, page 96.

would need to be extended over a period of several months, or even years, and, this, under the circumstances, of course, was out of the question.

The various samples may be classed as sewages (1, 7, 124, 128, 136); experimental effluents (137, 138, 139, 140, 141, 143, 145, 146, 147); and ordinary effluents (2, 3, 4, 8, 9, 125, 126, 127, 129, 130, 131, 132). The last are divided by Mr. Kershaw into final effluents (3, 9, 126, 127, 128, 131); general effluents (4, 130), first field effluent (2, 8, 125); and comparative samples (127, 129, and 131). As regards the comparative samples, 127 and 129 yielded fairly similar and not unsatisfactory results, whereas 131 gave very different and unsatisfactory results. The above instance may serve as an example of the difficulty experienced in interpreting the results obtained in the bacteriological examination of effluents from land processes of sewage treatment.

4. *Results in relation to tests other than the B. enteritidis sporogenes test.*

Up to the present, the records as regards the B. enteritidis sporogenes test have been chiefly considered. As regards other tests, it is to be noted that the average total number of bacteria in the sewage and effluents was as follows :—

——	Gelatine at 20° C. Microbes per c.c.	Agar at 37° C. Microbes per c.c.	Ratio.
Sewage - - - - - - - -	12,220,000	1,614,000	7·5 : 1
Effluents (inclusive of the experimental and first field effluents)	2,814,555 {77 per cent. reduction.}	260,550 {83 per cent. reduction.}	10·8 : 1
Effluents (exclusive of the experimental, but inclusive of the first field effluents)	701,363 {94 per cent. reduction.}	133,954 {91 per cent. reduction.}	5·2 : 1
Effluents (exclusive of the first field and experimental effluents)	532,777 {95 per cent. reduction.}	70,500 {95 per cent. reduction.}	7·5 : 1

The actual number of microbes remaining in the effluents is so great that too much stress must not be laid on the marked percentage reduction, as compared with sewage, effected in the effluent by the land treatment. The averages, however, even if the first field and experimental effluents be excluded, are considerably in excess of the suggested standard, viz., 100,000 (gelatine at 20° C.), and 10,000 (agar at 37° C.), bacteria per c.c.

The B. coli results as a rule were unsatisfactory, but three of the effluents (exclusive of the experimental effluents), contained less than 1,000 B. coli per c.c.

In the table and diagram illustrating Appendix III. (page 196), the results of the examination of effluents from different sewage farms by the "gas" and B. enteritidis sporogenes tests are brought into comparison. Only four samples from Leicester were, however, examined by the "gas" test. Of these only one gave a satisfactory result.

Indol test.—(Production of indol in broth culture, 5 days incubation at 37° C.).

The following results were obtained by the use of this test :—

Samples of sewage 128 and 136, both gave a positive result with ·00001 c.c.

Effluents 131, 137, 138, a positive result with ·00001 c.c.
,, 130, 143, 145, a positive result with ·0001 c.c.
,, 129, 132, 139, 140, 146, a positive result with ·001 c.c.
,, 147, a positive result with ·01 c.c.

As the standard suggested is a negative result with ·001 c.c., it is obvious that, with one exception, all the effluents were unsatisfactory. Nevertheless, of the other samples, five came within measurable distance of passing the provisional standard.

5. *Results of the bacteriological examinations of additional samples of subsoil water, brook water, and brook water mixed with effluent.*

The results of the examination of these samples is shown in Table 12.

Table 12.—Showing the results of the bacteriological examination of samples of brook water, subsoil water, &c., obtained from Leicester sewage farm.

Description of the Sample.	Total number of bacteria per c.c.		Number of B. coli (or closely allied forms) per c.c.	Number of Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in milk culture) per c.c.
	Gelatine at 20° C.	Agar at 37° C.		
1.	2.	3.	4.	
5. Subsoil water, 7 feet 6 inches deep (boulder clay) 15th November 1899.	1,320,000	89,000	100, not 1,000 -	Negative 10 c.c.
6. Anstey Brook water and effluent (below outfalls 1 and 2). 20th November 1899.	63,000	8,400	1,000 not 10,000 -	+ 1 – ·1 c.c. At least 1 but less than 10.
32. General effluent. 3rd September 1900.	560,000	45,000	1,000 not 10,000 - (Indol + ·001 c.c.)	+ 1 – ·1 c.c. At least 1 but less than 10.
133. Anstey Brook above effluent outfalls. 3rd September 1900.	540,000	71,000	1 not 10 - - - (Indol + 1 c.c, direct)	– 1 c.c. None in 1 c.c.
34. Anstey Brook and effluent (50 yards below 132). 3rd September 1900.	15,300	2,400	10 not 100 - - (Indol + ·1 c.c.)	+ ·1 – ·01 c.c. At least 10 but less than 100.
135. Same lower down (600 yards below 134). 3rd September 1900.	37,000	8,600	10 not 100 - - (Indol + ·1 c.c.)	+ 1 – ·1 c.c. At least 1 but less than 10.

The subsoil water (sample 5), was taken from a high portion of the farm which itself had never been actually sewaged, but which lay at a higher level about fifty yards from sewaged land. A hole was sunk in the boulder clay on 14th November, 1899, and the sample drawn at a depth of 7 feet 6 inches the following day. Owing to the presence of a vein of sandy marl, Mr. Kershaw is uncertain whether sewage contamination was altogether absent or not. The results were certainly unsatisfactory, as regards the total number of bacteria and B. coli present, but it is noteworthy that spores of B. enteritidis sporogenes were absent even from 10 c.c. of the water.

Experience of freshly made, shallow wells does not lead me to place much reliance on these results. The disturbance of the soil consequent to the digging operations introduces a factor impossible to estimate from the bacteriological point of view. To obtain results of real value a period of weeks, if not months, should have elapsed between the sinking of the hole and the collection of samples, and even then, unless multiple samples were examined, great discrimination would be called for in interpreting the results obtained.

As regards samples 132, 133, 134, and 135, it is of interest to note that 133, although containing a large total number of bacteria, contained less than 10 B. coli per c.c., and no spores of B. enteritidis sporogenes in a similar amount. It is difficult to say why samples 134 and 135, collected lower down the brook, and after receiving the effluent 132, should have contained fewer bacteria than 133. The B. coli results are more intelligible. The effluent above (132), the brook above effluent outfalls (133), the mixed brook and effluent water (134, 50 yards below 132), and the mixed brook and effluent water (135, 600 yards below 134), contained at least 1,000, 1, 10 and 10, B. coli, respectively, per c.c.

The same samples taken in the same order contained at least 1, none, at least 10 and 1 spores of B. enteritidis sporogenes, respectively, per c.c Sample 6 (brook water and effluent mixed), collected 20th November 1899, and turbid with rain water, contained 63,000 (gelatine at 20° C.) and 8,400 (agar at 37° C.) bacteria; 1,000 B. coli; and at least 1, but less than 10 spores of B. enteritidis sporogenes, respectively, per c.c.

6. *General Conclusions.**

Considered from the bacteriological point of view, none of the effluents were in a fit state to be turned into a drinking-water stream. The majority were even hardly in a proper condition to be discharged into non-drinking water rivers. Nevertheless, the fact that some of the effluents were sufficiently pure to be discharged into a non-drinking water stream, and that a fair number of them, although exception might be taken to them, came within measurable distance of satisfying reasonable standards, encourages the belief that by acquiring an increased area of land, the effluents from Leicester sewage farm might be made uniformly fairly good. Whether acquiring a further area of land is practicable or advisable is a separate question, and need not be discussed here. The only contention is that the results were not so uniformly and unmistakably unsatisfactory as to point to the impossibility of obtaining continuously good results with land of the kind available at Leicester.

Addendum A.—*Results of the examination by means of simple tests of samples obtained from Leicester sewage farm.* (Special comparative series of experiments.)

The tests employed were (1) the "gas," (2) B. enteritidis sporogenes, and (3) neutral red broth tests. The results are shown in Table 13 and Diagram 8.

It will be seen from Table 13 that, of fifteen (nine, excluding the 1st and 2nd field effluents) samples of effluent—

(1.) Four passed the gas test.

(2.) Five passed the B. enteritidis sporogenes test.

(3.) Three passed the neutral red broth test.

Further, it may be said that as regards tests (1) (2) (3) six, four, and five additional samples came within measurable distance of passing the respective standards. Roughly speaking, about one-half of the samples were fairly satisfactory, and of these about one-half (one-quarter of the total number) passed the standards set up for the various tests.

Addendum B.—*Additional notes.*

Animal inoculation experiments.—These are included in a separate report, but the following brief notes will not be out of place :—

Two guinea-pigs were inoculated subcutaneously, one with 2 c.c. of final effluent No. 3, and the other with 2 c.c. of final effluent No. 4. Both animals recovered from the effects of the injection.

A sample of Leicester crude sewage collected on 12th October, 1901, was treated as follows :

(a.) Heated to 65° C. for twenty minutes and rendered germ-free by filtration through a sterilised Pasteur filter.

(b.) Heated to 80° C. for ten minutes and rendered germ-free by filtration through a sterilised Pasteur filter.

(c.) Heated to 100° C. for one hour and rendered germ-free by filtration through a sterilised Pasteur filter.

Three guinea-pigs (a, b, c) were respectively inoculated each with 20 c.c. of the liquid filtered under (a), (b), and (c) set of conditions. The animals were seemingly but little, if at all, affected by the injections, and remained lively and well.

A sample of Leicester crude sewage, collected on 12th October, 1901, was filtered through a sterilised Pasteur's filter, and 20 c.c. of the filtrate were injected into a guinea-pig. The animal remained apparently unaffected.

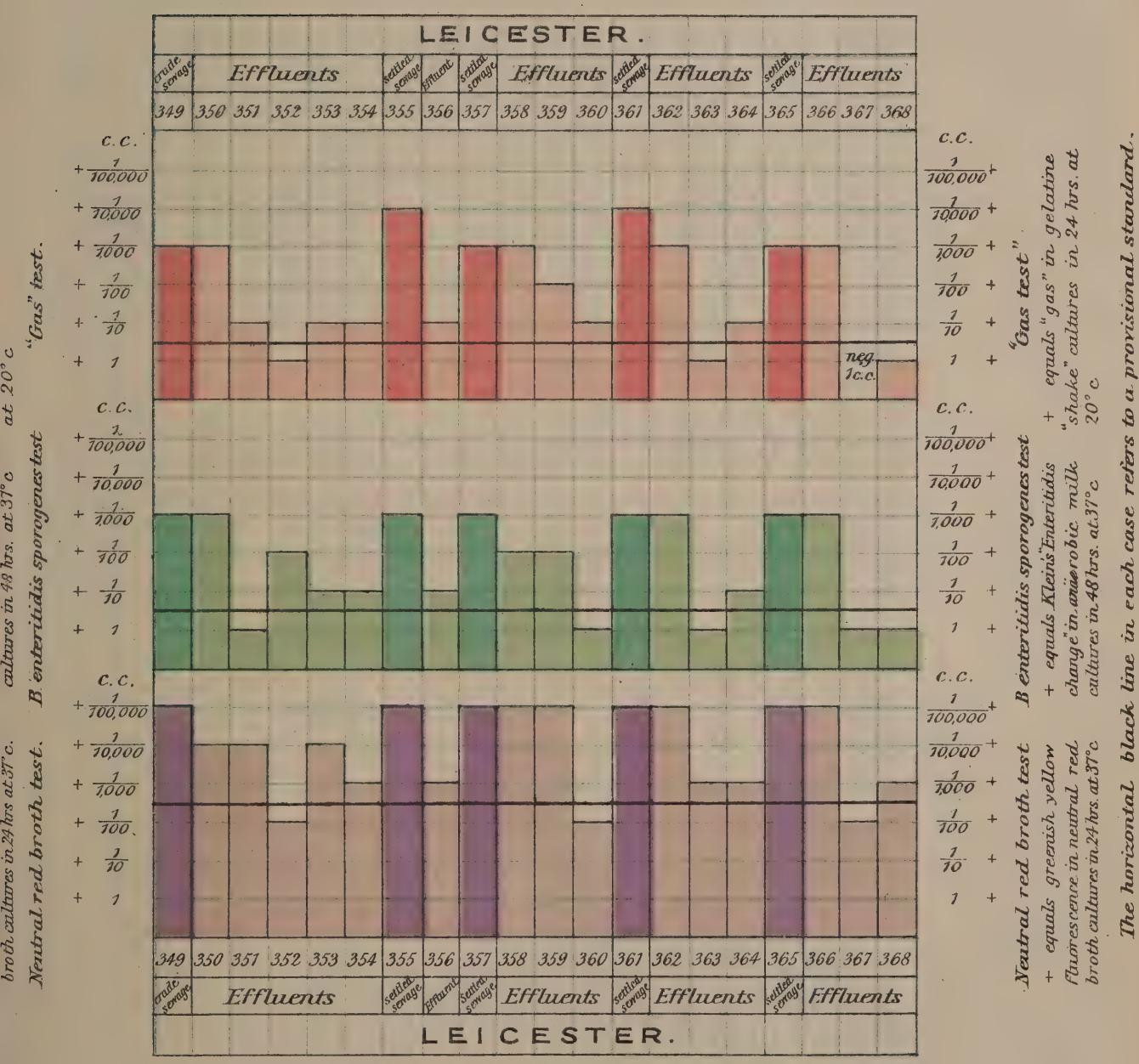
* In drawing these conclusions the results given in Addenda A and B have also been taken into consideration. For statistical information see tabular statement at the beginning of this Report, Section V.

TABLE 13.—Showing as regards the (a) "Gas," (b) B. enteritidis sporogenes, and (c) Neutral red broth tests, the results of the bacteriological examination of five samples of sewage and fifteen samples of effluent obtained from Leicester Sewage Farm.

[The double thin line in each case refers to a provisional standard (non-drinking water streams). The sign + occurring on the right hand side of these lines means that the effluent is condemned on the basis of this standard.]

Description of Sample.	"Gas" in gelatine "shake" cultures (24 hours at 20° C.).						Number of Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anaerobic milk cultures).						Neutral red broth test (24 hours at 37° C.): —Greenish yellow fluorescence = positive result. No change in colour = negative result.						Sewage Farm.
	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	
349 *Crude Sewage* (11.20 a.m., 30th September 1901, air 66° F., sample 64° F.)				+	−					+	−							+	Leicester.
350 Surface effluent from arable field (12 noon, 30th September 1901, air 66° F., sample 70° F.)				+						+							+		
351 Second effluent off rye grass (12.30 p.m., 30th September 1901, air 67° F., 60° F.		+	−				+	−									+		
352 Final or third effluent (1 p.m., 30th September 1901, air 67° F.; sample 59° F.)	+	−							+	−					+	−			
353 General effluent (A) (11.30 a.m., 1st October 1901, air 65° F., sample 58° F.)		+	−					+	−								+		
354 General effluent (B) (11.45 a.m., 1st October 1901, air 65° F., sample 59° F.)		+	−					+	−							+	−		
355 *Settled Sewage* (12 p.m., 1st October 1901, air 67° F., sample 64° F.)					+	−				+	−							+	
356 General effluent (C) (1 p.m., 1st October 1901, air 68° F., sample 59° F.)		+	−					+	−							+	−		
357 *Settled Sewage* (11.15 a.m., 2nd October 1901, air 62° F., sample, 65° F.)				+	−					+	−							+	
358 First effluent off arable land (11.30 a.m., 2nd October 1901, air 62° F., sample 65° F.)				+	−				+	−								+	
359 Second effluent off rye grass (12.30 p.m., 2nd October 1901, air 62° F., sample 61° F.)			+	−					+	−								+	
360 Final or third effluent from rye grass (1 p.m., 2nd October 1901, air 63° F., sample 62° F.)		+	−				+	−							+	−			
361 *Settled Sewage* (10.30 a.m., 3rd October 1901, air 60° F., sample 65° F.)					+	−				+	−							+	
362 First effluent off arable field (11.15 a.m., 3rd October 1901, air 66° F., sample 68° F.)				+	−					+	−							+	
363 Final effluent off permanent pasture and rye grass (12.15 p.m., 3rd October 1901, air 64° F., sample 62° F.)	+	−					+	−								+	−		
364 General effluent (12.45 p.m., 3rd October 1901, air 61° F., sample 61° F.)		+	−					+	−							+	−		
365 *Settled Sewage* (11 a.m., 4th October 1901, air 57° F., sample 64° F.)				+	−					+	−							+	
366 First effluent off arable field (11.30 a.m., 4th October 1901, air, 57° F., sample 54° F.)				+	−					+	−							+	
367 Final effluent (12.30 p.m., 4th October 1901, air 56° F., sample 54° F.)	−						+	−							+	−			
368 General effluent (1 p.m., 4th October 1901, air 56° F., sample 55° F.)	+	−					+	−								+	−		

Diagram 8 showing as, regards the (a) "gas"; (b) B. enteritidis sporogenes; & (c) neutral red broth tests, the results of the bacteriological examination of five samples of sewage & fifteen samples of effluent obtained from Leicester sewage farm.



Neller & Graham Ltd Litho. London.

A sample of effluent (No. 137) from Leicester sewage farm, collected on 12th September, 1900, was found to contain *B. pyocyaneus* in $\frac{1}{10}$ c.c. 0·5 c.c. of a broth culture was injected subcutaneously into a guinea-pig. The animal died within twenty-four hours. *B. pyocyaneus* in pure culture was recovered from the heart's blood of the animal.

Thermophilic bacteria (broth at 68° C.).

Effluent No. 4 and sample 6 (mixed brook-water and effluent) contained thermophilic bacteria in 1 c.c. Sample 5 (subsoil water) contained no thermophilic bacteria in 1 c.c.

Spores of aerobic bacteria.

Samples 1 (settled sewage), 3 (final effluent), 4 (effluent), 5 (subsoil water) contained 470, 870, 800 and 340 spores of aerobic bacteria, respectively, per c.c. B. mycoides was not noted in any of the cultures except in those made from No. 3. Here B. mycoides was present in the proportion of 10 per c.c.

Streptococci.

The pressure of other work for the Commission during the period covering the Leicester investigations prevented the employment of this difficult test, except on a few occasions, when unfortunately negative results were obtained. The samples tested were Nos. 1 (settled sewage), 3 (effluent), 4 (effluent), 5 (subsoil water), 6 (mixed brook-water and effluent). No streptococci could be found in $\frac{1}{10000}$, $\frac{1}{1000}$, $\frac{1}{10}$, $\frac{1}{10}$, $\frac{1}{10}$ c.c., respectively, of the above samples.

A few additional samples obtained during October, 1901, were examined, bacteriologically, as regards the total number of bacteria, and the number of B. coli and indol-producing bacteria. The following results were obtained :—

Description of Sample.	Number of bacteria per c.c.		Number of B. coli per c.c.	Indol test (indol in broth cultures, five days at 37° C.)
	Gelatine at 20° C.	Agar at 37° C.		
1.	2.	3.	4.	5.
349 Crude sewage - - - 1st October 1901.	32,600,000	4,500,000	100,000 - - -	+ ·00001 c.c.
352 Final effluent - - - 1st October 1901.	41,000	2,700	Negative $\frac{1}{1000}$ c.c. -	Negative $\frac{1}{1000}$ c.c.
353 General effluent - - 2nd October 1901.	830,000	225,000	1,000 not 10,000 - -	+ ·0001 c.c.
354 General effluent - - 2nd October 1901.	940,000	119,000	- ditto - - - -	+ ·001 ; – ·0001 c.c.

Of the three effluents only one (352) could be regarded as satisfactory on the basis of the tests employed.

Addendum C.—*Mr. Kershaw's Abridged Notes to accompany Bacteriological Data.**

LEICESTER SEWAGE FARM.

Domestic Sewage and Trade Refuse.

Additional Notes.

Sample No. 1.—Taken after heavy rain, and rather dilute.

Sample No. 2.—Surface effluent means one which has travelled over the surface of the land and has not reached the under-drains. After the sewage had passed over the first field all samples were almost invariably surface and filtration effluents, as these effluents are collected in a manhole at the lowest point of the first field and sent on to the next field mixed together. No. 2 sample contained some suspended matter and was slightly turbid

Sample No. 3.—Taken during a sharp shower which apparently affected the effluent as regards suspended matter, and turbidity.

Sample No. 4.—General effluent. The sewage from which this effluent was derived was very soapy.

Sample No. 5.—Subsoil water taken from a high portion of the farm which had never been actually sewaged within 50 yards. The sample was from a small sandy stratum in the boulder clay.

Sample No. 6.—Water rather turbid at time of drawing. (Taken 80 yards below effluent outfall.)

Sample No. 7.—Screened and settled sewage, normal.

Sample No. 124.—Screened and settled sewage.—The tank had been cleaned out the day previous to drawing samples, and the settled sewage appeared to contain less suspended matter.

Sample No. 126.—The grass land this effluent came off was in very good condition,

Sample No. 127B.—Brook very low, water clear.

Sample No. 128.—Sewage rather strong.

Sample No. 130A.—Brook low.

Sample No. 131.—Final effluent turbid; some fragments of straw. Bullocks in field probably stirred up some sediment.

Sample No. 132.—General effluent taken from two general effluent outfalls, both flowing at about the same rate. Half a sample bottle taken from each outlet.

Sample No. 133.—Brook about normal and very fairly clear.

† Sample No. 134.—A fairly clear sample.

† Sample No. 135.—A fairly clear sample.

Experiment.

The following samples were taken with a view to ascertaining by daily increased doses of sewage the limit of the purifying power of the soil. The daily increment being about 3000 gallons:—

Sample No. 136.—When this sample was drawn the tanks were being cleaned out, and only one was in use instead of three. The sample did not appear to be particularly strong.

Sample No. 137.—Final effluent, fairly clear. The sewage was run over an arable field first (6·5 acres) and then on to a pasture field (10·5 acres); total, 17·0 acres. The arable field was stubble, and there was very little grass on the pasture field, the bullocks only having been taken off that day. The dose of sewage was started at about 200,000 gallons for the 17 acres per 24 hours, on September 10th, 1900, at noon.

Sample No. 137.—Owing to the small amount of sewage being applied, only about 2 acres of the arable and 4·5 acres of the pasture were covered by the sewage; the effluent then reaching the drains through cracks in the soil, and could only be obtained after mixing with an effluent from another field.

Sample No. 138.—This sample was drawn before having mixed with the other effluent. About 2·5 acres arable and 4·5 acres pasture were now covered by the sewage.

The effluent did not appear to be good. About 265,000 gallons of sewage were being sent on to the area‡.

Owing to the dryness of the soil, it was thought advisable to soak the land thoroughly, that being the method usually employed in irrigating the land, and on September 13th 900,000 gallons of sewage per 24 hours were put on the land for 3 days, 3·5 acres arable and 4·75 pasture being covered on September 14th, and the grass appeared to have benefited considerably where irrigated.

On September 15th 4·75 acres arable and 4·75 acres pasture were being irrigated, and a large quantity of surface effluent was flowing from the grass land, which had greatly improved in appearance. The effluent too appeared better.

On September 16th the whole 6·5 acres of arable and 5 acres pasture were being irrigated, and some surface effluent was flowing off the arable. The flow of sewage at noon was cut down from 900,000 gallons to 200,000 gallons for the entire area.

---

* In a few instances samples are referred to in this Addendum concerning which no bacteriological records are available. These were extra samples collected by Mr. Kershaw for chemical analysis.

† With regard to these samples, it appeared likely from the nature of the soil adjoining the brooks, that percolation of effluent from the farm might under certain circumstances find its way into the brook at various points.

‡ When small quantities of sewage are run on to land, the sewage nearly always has a tendency to follow certain defined channels, but when the entire surface has been thoroughly wetted, the sewage flows over the surface far more evenly.

Sample No. 139. September 17th.—There was not much effluent coming off the pasture land, and it did not appear to be very good. The flow was increased to 250,000 gallons at noon.

Sample No. 140. September 18th.—There was still very little effluent coming off the pasture. A clearer sample than No. 139, Sewage flow increased to 300,000 gallons at noon.

Sample No. 141. September 19th.—This sample was not so yellow in colour as the previous ones, and had very little smell. A good crop of grass on the irrigated portion. Sewage flow increased to 350,000 gallons at noon.

Sample No. 142. September 20th.—A clearer sample than previously. Sewage flow increased to 400,000 gallons at noon.

Sample No. 143. September 21st.—This sample did not look so good as the preceding one. This may perhaps be accounted for by the fact that the arable land effluent was removed to another portion of the pasture land, in order to give the part previously sewaged a rest, as it was becoming over sewaged. This would be equivalent to starting a new field. There was an exceedingly poor crop of grass on the non-irrigated portions of the field. Sewage flow increased to 450,000 gallons at noon.

Sample No. 144. September 22nd.—This sample of effluent seemed very bad, probably owing to a new piece of pasture land being irrigated. Flow increased to 500,000 gallons at noon.

Sample No. 144A. September 23rd.—The effluent appeared clearer than the day previous. Flow increased to 550,000 gallons at noon.

Sample No. 145. September 24th.—The effluent seemed improving, very slight smell. Grass commencing to grow well. Flow increased to 600,000 gallons at noon.

Sample No. 146. September 25th.—Effluent had a slight smell. The grass appeared to be deteriorating, the amount going on appearing to be about the limit the grass land can take without injury. Flow increased to 650,000 gallons at noon.

Sample No. 147. September 26th.—The effluent appeared better. A vast quantity of small white worms in the sewage, and also in the effluent. Those in the sewage varied in length from $\frac{1}{4}$ inch to $\frac{1}{2}$ inch, and those in the effluent were about $\frac{1}{64}$ inch long. Flow increased to 700,000 gallons at noon.

Sample No. 148. September 27th.—Not much change in the effluent apparently, the grass not looking so well, and much sediment round the roots.

End of experiment.

Sample No. 350.—First field effluent, turbid and strong sewage smell. Owing to the tanks being cleaned out; some sewage was being pumped directly on to this field, stirring up the silt.

Sample No. 354.—General effluent, very yellow colour. This is especially noticeable when bullocks have been upon the irrigated area, and the grass bruised and trampled upon.

Sample No. 356.—General effluent, very frothy on being shaken.

Sample No. 358.—First field effluent; a lot of suspended matter coming off the arable field.

Sample No. 362.—First field effluent, black and septic looking.

Sample No. 365.—Settled sewage after heavy rain, not much sediment.

Sample No. 366.—Some flocculent suspended matter.

LEICESTER SEWAGE FARM.

Domestic Sewage and Trade Refuse.

Number of Sample.	Date of Drawing Sample.	Time of day.	Rainfall Day previous to drawing Sample.	Rainfall Day of drawing Sample.	Air Temperature time of drawing Sample.	Temperature of Sample.	Maximum Temperature during the 24 hours.	Minimum Temperature during the 24 hours.	Humidity (9 a.m.)	Dissolved Oxygen in Sample.	Brief description of Sample.	Remarks.
	1899:		Inches.	Inches.	°C. °F.	°C. °F.	°C. °F.	°C. °F.		cc.		
1	8 November	11.15 a.m.	·07	·24	11·1 (52)	12·7 (55)	—	—	—	—	Screened and settled sewage.	Mean daily maximum temperature, 10·7 °C. (51·3) °F.
2	8 „	12.30 p.m.	·07	·24	11·1 (52)	11·1 (52)	—	—	—	—	First field effluent.	Mean daily minimum temperature, 3·6 °C. (38·6) °F.
3	8 „	3 „	·07	·24	10·0 (50)	9·4 (49)	—	—	—	—	Final effluent.	Mean daily rainfall, ·046 inch.
4	14 „	3 „	·00	·00	10·0 (50)	9·4 (49)	—	—	—	—	§ General effluent.	(For the period 8th November to 21st November 1899).
5	15 „	1.15 „	·00	·00	9·4 (49)	10·5 (51)	—	—	—	—	Subsoil water.	
6	20 „	2.30 „	·00	·04	9·4 (49)	9·4 (49)	—	—	—	—	Brook water and effluent.	Samples which may have been affected by rainfall are underlined.
7	21 „	12 (noon)	·04	·01	7·2 (45)	14·4 (58)	—	—	—	—	Screened and settled sewage	
8	21 „	1.30 p.m.	·04	·01	7·2 (45)	7·2 (45)	—	—	—	—	First field effluent.	§ By "general effluent" is meant a mixture of two or more finally treated effluents on leaving the farm.
9	21 „	2.45 „	·04	·01	6·6 (44)	6·6 (44)	—	—	—	—	Final effluent.	
	1900:											
	21 August	12.30 p.m.	·00	·15	20·5 (69)	17·7 (64)	21·6 (71)	10·5 (51)	—	2·0	Screened and settled sewage.	Mean daily maximum temperature, 20·4 °C. (68·86) °F.
125	21 „	1.30 „	·00	·15	22·2 (72)	21·1 (70)	21·6 (71)	10·5 (51)	—	2·0	First field effluent.	Mean daily minimum temperature, 8·5 °C. (47·31) °F.
126	21 „	3.15 „	·00	·15	21·6 (71)	20·0 (68)	21·6 (71)	10·5 (51)	—	5·0	Final effluent.	Mean daily rainfall, ·048 inch.
127a	22 „	12 (noon)	·15	·00	18·8 (66)	21·6 (71)	21·1 (70)	12·7 (55)	—	3·50	Intermediate effluent.	(For the period 20th August to 10th September 1900).
127b	22 „	1 p.m.	·15	·00	16·1 (61)	17·7 (64)	21·1 (70)	12·7 (55)	—	6·50	Brook water.	
127	22 „	2 „	·15	·00	16·6 (62)	18·8 (66)	21·1 (70)	12·7 (55)	—	5·50	Final effluent.	
128a	27 „	12 15 „	·02	·00	17·7 (64)	17·2 (63)	17·7 (64)	11·6 (53)	—	2·75	Intermediate effluent.	
128	27 „	11.15 a.m.	·02	·00	15·5 (60)	15·5 (60)	17·7 (64)	11·6 (53)	—	—	Screened and settled sewage.	
129	27 „	12 (noon)	·02	·00	16·1 (61)	16·6 (62)	17·7 (64)	11·6 (53)	—	3·0	Final effluent.	

130a	29 „	12 (noon)	·00	·00	16·6	(62)	14·4	(58)	21·6	(71)	9·4	(49)	—	5·50	Brook water.	
130	29 „	11.45 a.m.	·00	·00	16·1	(61)	14·4	(58)	21·6	(71)	9·4	(49)	—	2·0	General effluent.	
131	30 „	11.30 „	·00	·00	18·8	(66)	17·7	(64)	25·0	(77)	6·6	(44)	—	0·50	Final effluent.	
132	3 September	11.45 „	·00	·00	17·2	(63)	15·0	(59)	17·7	(64)	5·5	(42)	—	3·50	General effluent.	
133	3 „	12 (noon)	·00	·00	17·2	(63)	13·3	(56)	17·7	(64)	5·5	(42)	—	6·50	Brook water above effluent outfalls.	
134	3 „	12.30 p.m.	·00	·00	16·6	(62)	13·8	(57)	17·7	(64)	5·5	(42)	—	6·00	Brook water and effluent.	
135	3 „	1 „	·00	·00	17·7	(64)	14·4	(58)	17·7	(64)	5·5	(42)	—	5·00	„ „ „ „	
					EXPERIMENT.											
136	10 „	12 (noon)	·00	·00	18·3	(65)	17·2	(63)	18·8	(66)	5·5	(42)	—	—	Screened and settled sewage.	Mean daily maximum temperature, 21·2 °C (70·17) °F.
137	11 „	1 p.m.	·00	·00	15·0	(59)	15·5	(60)	23·3	(74)	6·1	(43)	—	3·75	Final effluent.	Mean daily minimum temperature, 7·2 °C (45·29) °F.
138	12 „	12 „	·00	·00	22·7	(73)	17·2	(63)	20·5	(69)	5·0	(41)	—	3·0	„ „	Mean daily rainfall, ·009 inch.
139	17 „	12 „	·02	·00	18·3	(65)	16·6	(62)	22·7	(73)	8·3	(47)	—	1·25	„ „	For the period 11th September to 27th September 1900.
140	18 „	12 „	·00	·02	17·2	(63)	16·6	(62)	21·6	(71)	1·1	(34)	—	1·50	„ „	
141	19 „	12 „	·02	·00	20·5	(69)	20·5	(69)	19·4	(67)	2·7	(37)	—	1·75	„ „	
142	20 „	12 „	·00	·00	18·8	(66)	14·4	(58)	21·6	(71)	8·3	(47)	—	1·75	„ „	
143	21 „	12 „	·00	·00	22·2	(72)	16·1	(61)	23·3	(74)	12·7	(55)	—	1·50	„ „	
144	22 „	12 „	·00	·00	22·2	(72)	17·2	(63)	23·8	(75)	13·3	(56)	—	0·75	„ „	
44a	23	12 „	·00	·00	18·3	(65)	17·2	(63)	21·6	(71)	10·5	(51)	—	--	„ „	
145	24 „	12 „	·00	·02	15·5	(60)	13·8	(57)	20·0	(68)	3·8	(39)	—	2·0	„ „	
146	25 „	12 „	·02	·00	18·3	(65)	16·1	(61)	16·1	(61)	6·6	(44)	—	·25	„ „	
147	26 „	12 „	0·0	·06	15·0	(59)	13·3	(56)	18·8	(66)	11·6	(53)	—	2·0	„ „	
148	27 „	12 „	0·6	·04	17·7	(64)	14·4	(58)	20·0	(68)	13·3	(56)	—	2·50	„ „	
349	1901 : 30 September	11.30 a.m.	·00	·00	18·8	(66)	17·7	(64)	21·1	(70)	12·2	(36)	—	--	Screened sewage.	Mean daily maximum temperature, 19·3 °C (66·8) °F.
350	30 „	12 (noon)	·00	·00	18·8	(66)	21·1	(70)	21·1	(70)	12·2	(36)	—	—	First field effluent.	Mean daily minimum temperature, 6·5 °C (43·8) °F.
351	30 „	12.30 p.m.	·00	·00	19·4	(67)	15·5	(60)	21·1	(70)	12·2	(36)	—	—	Second field effluent.	Mean daily rainfall ·035 inch.
352	30 „	1 „	·00	·00	19·4	(67)	15·0	(59)	21·1	(70)	12·2	(36)	—	—	Final effluent.	For the period 30th September to 4th October 1901.

LEICESTER SEWAGE.—DOMESTIC SEWAGE AND TRADE REFUSE.—(Continued).

Number of Sample.	Date of drawing Sample.	Time of day.	Rainfall day previous to drawing Sample.	Rainfall day of drawing Sample.	Air temperature time of drawing Sample.	Temperature of Sample.	Maximum temperature during the 24 hours.	Minimum temperature during the 24 hours.	Humidity (9 a.m.)	Dissolved oxygen in Sample.	Brief description of Sample.	REMARKS.
	1901:		Inches.	Inches.	°C. °F.	°C. °F.	°C. °F.	°C. °F.		c.c.		
353	1 October -	11.30 a.m. -	·00	·03	18·3 (65)	13·3 (56)	20·0 (68)	6·6 (44)	—	—	General effluent.	
354	1 „ -	11.45 „ -	·00	·03	18·3 (65)	15·0 (59)	20·0 (68)	6·6 (44)	—	—	„ „	
354 A	1 „ -	—	—	—	—	—	—	—	—	—	Screened sewage.	
355	1 „ -	12 (noon) -	·00	·03	19·4 (67)	17·7 (64)	20·0 (68)	6·6 (44)	—	—	Screened and settled sewage.	
356	1 „ -	1 p.m. - -	·00	·03	20·0 (68)	15·0 (59)	20·0 (68)	6·6 (44)	—	—	General effluent.	
357	2 „ -	11.15 a.m. -	·03	·005	16·6 (62)	18·3 (65)	20·0 (68)	10·0 (50)	—	—	Screened and settled sewage.	
358	2 „ -	11.30 „ -	·03	·005	16·6 (62)	18·3 (65)	20·0 (68)	10·0 (50)	—	—	First field effluent.	
359	2 „ -	12.30 p.m. -	·03	·005	16·6 (62)	16·1 (61)	20·0 (68)	10·0 (50)	—	—	Second field effluent.	
360	2 „ -	1 „ -	·03	·005	17·2 (63)	16·6 (62)	20·0 (68)	10·0 (50)	—	—	Final effluent.	
361	3 „ -	10.30 a.m. -	·005	·00	15·5 (60)	18·3 (65)	18·3 (65)	6·6 (44)	—	—	Screened and settled sewage.	
362	3 „ -	11.15 „ -	·005	·00	18·8 (66)	20·0 (68)	18·3 (65)	6·6 (44)	—	—	First field effluent.	
363	3 „ -	12.15 p.m. -	·005	·00	17·7 (64)	16·6 (62)	18·3 (65)	6·6 (44)	—	—	Final effluent.	
364	3 „ -	12.45 „ -	·005	·00	16·1 (61)	16·1 (61)	18·3 (65)	6·6 (44)	—	—	General effluent.	
365	4 „ -	11 a.m. -	·00	·14	13·8 (57)	17·4 (64)	17·2 (63)	7·2 (45)	—	—	Screened and settled sewage.	
366	4 „ -	11.30 „ -	·00	·14	13·8 (57)	12·2 (54)	17·2 (63)	7·2 (45)	—	—	First field effluent.	
367	4 „ -	12.30 p.m. -	·00	·14	13·3 (56)	12·2 (54)	17·2 (63)	7·2 (45)	—	—	Final effluent.	
368	4 „ -	1 „ -	·00	·14	13·3 (56)	12·7 (55)	17·2 (63)	7·2 (45)	—	—	General effluent.	
	1902.											
469	11 February -	12.30 p.m. Mon. to 11.30 a.m. Tues.	3″ snow	·00	—	—	—	—	—	—	Screened and settled sewage.	24 hours samples.
470	12 „ -	12 30 p m. Tues. to 11.30 a.m. Wed.	·00	·00	—	—	—	—	—	—	Screened and settled sewage.	24 hours samples.
471	13 „ -	12.30 Wed. to 11.30 Thurs.	·00	·00	—	—	—	—	—	—	Screened and settled sewage.	24 hours samples.

LEICESTER SEWAGE FARM.

(Domestic Sewage and Trade Refuse).

Table of Samples other than Sewage.

Number of Sample.	Number of times the sewage was passed over the soil.	Area of plot or plots sewaged at the time of drawing sample.	Length of time these plots had been sewaged previously to drawing sample.	Nature of crops grown on plots.	Remarks.
		Acres.	Days.		
2	Once.	13·59	*38	Arable (no crops) - -	Sample consisted of surface and filtration effluents.
	Three times.	14·59 11·30	38	Permanent pasture -	Very slight sewage smell; rain during drawing of samples stirred up sediment on fields somewhat. Surface effluent.
4	Twice.	8·57 16·90	27 27	Arable and permanent pasture.	General effluent, slight sewage smell.
	—	—	—	——	Subsoil water, drawn 7 ft. 6 ins. deep from sand partings in the boulder clay, chalky appearance
6	—	—	—	——	Water from the Anstey Brook, drawn below outfalls Nos. 1 and 2. (Brook rather high).
8	Once.	6·87	32	Arable (no crops) - -	*Slight sewage smell. Surface effluent and filtration effluent. All fields sewaged *continuously both day and night,*
9	Twice.	10·7	32	Permanent pasture -	Surface and filtration effluent, very little smell.
125	Once.	6·34	12	Fallow (no crops) - -	Surface and filtration effluent, slight sewage smell.
126	Twice.	16·90	12	Permanent pasture -	Surface and filtration effluent, very slight sewage smell.
127a	Once.	19·18	13	Fallow (no crops) - -	Surface and filtration effluent, slight sewage smell.
127b	—	—	—	——	Water from Anstey Brook above the effluent outfalls. (Brook rather low).
127	Twice.	22·25	13	Permanent pasture -	Surface and filtration effluent.
128a	Once.	19·18	18	Fallow (no crops) - -	,, ,, ,,
129	Twice.	22·25	18	Permanent pasture -	,, ,, ,,
130a	—	—	—	——	Water from the Anstey Brook above the effluent outfalls; volume of brook about 1·5 million gallons per 24 hours.
130	—	—	—	——	Water from Anstey Brook general effluent.
131	Twice.	19·18 22·25	21 21	Fallow and permanent pasture.	Water from Anstey Brook effluent, sewage smell.
132	—	—	—	——	General effluent; about 1,000,000 gallons flowing per 24 hours.
133	—	—	—	——	Water from Anstey Brook above effluent outfalls; brook about normal.
134	—	—	—	——	Effluent and brook water 50 yards below sample No. 132.
135	—	—	—	——	Effluent and brook water 600 yards below sample No. 134.
137	Twice.	6·5 10·5	1	Fallow and permanent pasture (stubble).	Filtration sample, no surface effluent.
138	,,	10·5	2	Fallow and permanent pasture (stubble).	Filtration and surface effluent.
139	,,	10·5	7	Fallow and permanent pasture (stubble).	Filtration and surface effluent after field had received a soaking of sewage.
140	,,	10·5	8	Fallow and permanent pasture (stubble).	Filtration and surface effluent.
141	,,	10·5	9	Fallow and permanent pasture (stubble).	,, ,, ,,
142	,,	10·5	10	Fallow and permanent pasture (stubble).	,, ,, ,,
143	,,	10·5	11	Fallow and permanent pasture (stubble).	,, ,, ,,
144	,,	10·5	12	Fallow and permanent pasture (stubble).	Filtration and surface effluent. Effluent very bad.
144a	,,	10·5	13	Fallow and permanent pasture (stubble).	Filtration and surface effluent.
145	,,	10·5	14	Fallow and permanent pasture (stubble).	,, ,, ,,
146	,,	10·5	15	Fallow and permanent pasture (stubble).	,, ,, ,,
147	,,	10·5	16	Fallow and permanent pasture (stubble).	,, ,, ,,
148	,,	10·5	17	Fallow and permanent pasture (stubble).	,, ,, ,,

LEICESTER SEWAGE FARM—*continued.*

Number of Sample.	Number of times the sewage was passed over the soil.	Area of plot or plots sewaged at the time of drawing Sample.	Length of time those plots had been sewaged previously to drawing sample.	Nature of crops grown on plots.	Remarks.
		Acres.	Days.		
350	Once	19·28	20	Fallow (no crops) - -	Surface effluent, sewage smell.
351	Twice	12·77	21	Rye grass and permanent pasture.	Surface effluent.
352	3 times	5·88	10	Permanent pasture -	Surface effluent, a clear sample.
353	—	—	—	Fallow and permanent pasture.	Surface effluent, general effluent.
354	—	—	—	Fallow and permanent pasture.	Surface effluent sample. General effluent.
356	—	—	—	Fallow and permanent pasture.	Surface effluent sample. General effluent.
358	Once	19·28	22	Fallow (no crops) - -	Surface effluent.
359	Twice	12·77	23	Fallow, rye, and permanent pasture	Surface and filtration.
360	3 times	5·88	12	Fallow, rye, and permanent pasture.	" "
362	Once	19·28	23	Fallow (no crops) - -	Surface effluent.
363	3 times	12·77 5·88	13	Fallow, rye, and permanent pasture.	Surface and filtration effluent.
364	—	—	—	Fallow, rye, and permanent pasture.	Surface and filtration effluent. General effluent.
366	Once	19·28	24	Fallow (no crops) - -	Surface effluent.
367	3 times	12·77 5·88	14	Fallow, rye, and permanent pasture.	Surface and filtration effluent.
368	—	—	—	Fallow, rye, and permanent pasture.	Surface and filtration effluent, General effluent.

LEICESTER SEWAGE FARM.

* Comparative Samples, or samples taken from the same plots of land.

First (or arable) field effluents.	Second field (pasture or rye grass) effluents.	Final Effluents.	Remarks.
Nos. (127a) (128a)	Nos.	Nos. (127) (129) (131)	* By comparative samples is meant samples drawn from the same areas of land, and the effluents in brackets are comparable with each other so far as the area of the land sewaged is concerned.
(350) (358) (362) (366)	(351) (359)	(352)† (360) (363) (367)	† Samples Nos. 352–367 were treated on (or had passed over) three fields.

SECTION VI.

SOUTH NORWOOD SEWAGE FARM.

1. Situation of farm.—Closely adjacent to South Norwood.

2. Total acreage of farm.—191 acres.

3. Total irrigable area.—152 acres.

4. Average area irrigated at one time.—50 acres.

5. Population draining to farm—21,000..

6. Population per acre irrigated.—138.

7. Gallons of sewage per head per day.—28·5.

8. Dry-weather flow of sewage per 24 hours.—600,000 gallons.

9. Gallons of sewage (exclusive of storm water) treated per acre per 24 hours.—12,000—$(\frac{600000}{50})$.

10. Gallons of sewage treated per acre per 24 hours, on the assumption that each acre of irrigable area is under sewage all the time (this for purpose of comparison $(\frac{600000}{152})$—4,000 gallons.

11. Characters of the sewage.—Purely domestic.

12. Method of treatment.—Screening, settling tanks, and surface irrigation.

13. General characters of the soil and subsoil.—A clay soil resting on clay.

14. Separate or combined sewerage system.—Partially separate.

15. The final effluent is discharged into.—Chaffinch Beck.

16. Number of years farm in operation before 1900.—36 years.

A full description of South Norwood Sewage Farm will be found in Mr. Kershaw's report. (Part IV. Engineering and Practical Report.) Here it is permissible only to note very briefly a few of the more important points.

The soil of the farm is clay, resting on clay. There is practically no subsoil water on the farm and only very little gains access to the sewers. The sewage is entirely domestic. The sewerage system is partially separate. The method of treatment may be described as settling, screening, and surface irrigation with some filtration. The sewage is treated at least twice, the number of times depending a great deal on the size and length of the plots in relation to the line of flow of the sewage. There are no storm overflows, and consequently during heavy storms the farm has to treat a greatly-increased volume of sewage. About one-sixth of the irrigable area is under-drained. Mangolds, oats, and mint are grown on the farm, but the staple crop is rye-grass. The effluents flow into a ditch which joins the Chaffinch Brook close to the farm. "*The total area of the farm is* 191 *acres ;* 152 *acres are actually irrigated, and this area deals with* 600,000 *gallons of sewage (excluding storm water) per* 24 *hours. With the present population and* 28·5 *gallons of sewage per head this amounts to* 138·15 *persons, or about* 4,000 *gallons per acre. About one-third of the total available irrigable area is used at one sewaging, which corresponds to about* 12,000 *gallons per acre per day.*"

The following is a summary of the several sections of the report in so far as it relates to South Norwood Sewage Farm :—

1. Tabular Statement and Summary of the chief bacteriological results.

2. Diagram 9 illustrating the results shown in Table 14 with comments thereon.

3. Results considered in relation to Mr. Kershaw's notes.

4. Results in relation to tests other than the B. enteritidis sporogenes test.

5. Results of the bacteriological examination of additional samples of brook water, mixture of brook water and effluent, and samples of street "washings."

6. General conclusions.

Addendum A.—Comparative records as regards (a), the "gas," and (b), B. enteritidis sporogenes tests of samples obtained from South Norwood as well as other sewage farms.

Addendum B.—Additional bacteriological notes.

Addendum C.—Mr. Kershaw's abridged notes to accompany bacteriological data.

1. *Tabular Statement and Summary of the chief bacteriological results.*

The following table (Table 14) shows as regards the total number of bacteria, B. coli, and spores of B. enteritidis sporogenes, the results of the bacteriological examination of four samples of sewage and thirty-three samples of effluent.

TABLE 14.—Showing as regards the total number of bacteria, B. coli, and spores of B enteritidis sporogenes, the results of the bacteriological examination of samples of sewage and effluents obtained from South Norwood Sewage Farm.

Description of the Sample.	Total Number of bacteria per c.c.		Number of B. coli (or closely allied forms) per c.c.	Number of Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in milk culture) per c.c.	
	Gelatine at 20° C.	Agar at 37° C.			
1.	2.	3.	4.	5.	
21 Settled sewage - - - 2.15 p.m., 9th Jan. 1900.	12,800,000	2,050,000	At least 100,000 -	+ ·01, – ·001 c.c. At least 100 but less than 1,000.	
28 Settled sewage - - - 2.45 p.m., 22nd Jan. 1900.	53,000,000	6,500,000	- ditto - -	- ditto - ditto.	
170 Crude sewage - - - 12 noon, 7th Nov. 1900.	69,200,000	11,840,000	- ditto - -	+ ·001, – ·0001 c.c. At least 1,000 but less than 10,000.	
176 Settled sewage - - - 12 noon, 20th Nov. 1900.	59,400,000	5,040,000	- ditto - -	+ ·001 c.c. At least 1,000.	
Average - - -	48,600,000	6,357,500	[Ratio cols. 2 to 3 = 7·6 : 1]		
22 First field effluent - - 3.15 p.m., 9th Jan. 1900.	2,430,000	370,000	10,000 not 100,000 -	+ ·01, – ·001 c.c. At least 100 but less than 1,000.	First visit, January and February 1900.
23 Final effluent - - - 5.15 p.m., 9th Jan. 1900.	2,336,000	108,800	At least 1,000 -	+ ·01 c.c. At least 100.	First visit, January and February 1900.
25 First field effluent - - 2 p.m., 16th Jan. 1900	12,800,000	770,000	At least 100,000 -	+ ·1, – ·01 c.c. At least 10 but less than 100.	First visit, January and February 1900.
26 Final effluent - - - 3 p.m., 16th Jan. 1900.	760,000	26,000	1,000 not 10,000 -	+ 1, – ·1 c.c. At least 1 but less than 10.	First visit, January and February 1900.
27 First field effluent - - 2.45 p.m., 16th Jan. 1900.	8,400,000	700,000	At least 100,000 -	+ ·01, – ·001 c.c. At least 100 but less than 1,000.	First visit, January and February 1900.
29 Second field effluent - - 4 p.m., 22nd Jan. 1900.	112,000	1,800	100 not 1,000 - -	+ 1, – ·1 c.c. At least 1 but less than 10.	First visit, January and February 1900.
30 Final effluent - - - 4.45 p.m., 22nd Jan. 1900.	414,000	16,600	- ditto - -	- ditto - ditto.	First visit, January and February 1900.
31 General effluent - - - 4 p.m., 30th Jan. 1900.	1,620,000	83,000	1,000 not 10,000 -	+ ·01, – ·001 c.c. At least 100 but less than 1,000.	First visit, January and February 1900.
35 General effluent - - - 3.30 p.m., 29th Jan. 1900.	1,570,000	66,000	At least 1,000 -	- ditto - ditto.	First visit, January and February 1900.
171 Final effluent - - - 2.30 p.m., 7th Nov. 1900.	96,000	8,900	At least 10 - -	+ ·1, – ·01 c.c. At least 10 but less than 100.	Second visit, November and December 1900, and January 1901.
175 Final effluent - - - 2.45 p.m., 14th Nov. 1900.	183,400	5,100	10 not 100 - -	+ ·01, – ·001 c.c. At least 100 but less than 1,000.	Second visit, November and December 1900, and January 1901.
177 First field effluent - - 1 p.m., 20th Nov. 1900.	11,200,000	3,664,000	At least 100,000 -	- ditto - ditto.	Second visit, November and December 1900, and January 1901.
178 Final effluent - - - 3 p.m., 20th Nov. 1900.	19,200	980	At least 10 - -	+ ·1, – ·01 c.c. At least 10 but less than 100.	Second visit, November and December 1900, and January 1901.
180 Final effluent - - - 1.45 p.m., 21st Nov. 1900.	6,700	1,040	100 not 1,000 - -	+ 1, – ·1 c.c. At least 1 but less than 10.	Second visit, November and December 1900, and January 1901.
181 First field effluent - - 2.15 p.m., 27th Nov. 1900.	7,280,000	1,260,000	At least 10,000 -	+ ·1, – ·01 c.c. At least 10 but less than 100.	Second visit, November and December 1900, and January 1901.
183 First field effluent - - 1.30 p.m., 28th Nov. 1900.	4,360,000	400,000	- ditto - -	- ditto - ditto.	Second visit, November and December 1900, and January 1901.
184 General effluent - - - 2.15 p.m., 28th Nov. 1900.	3,800,000	148,000	- ditto - -	- ditto - ditto.	Second visit, November and December 1900, and January 1901.
185 Final effluent - - - 2.45 p.m., 29th Nov. 1900.	284,000	5,100	At least 100 - -	None in 1 c c.	Second visit, November and December 1900, and January 1901.
186 Final effluent - - - 11.45 a.m., 30th Nov. 1900.	—	—	—	+ 1, – ·1 c.c. At least 1 but less than 10.	Second visit, November and December 1900, and January 1901.

Experimental effluents.

TABLE 14—*continued.*

Description of the Sample.	Total Number of bacteria per c.c.		Number of B. coli (or closely allied forms) per c.c.	Number of Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in milk culture) per c.c.	
	Gelatine at 20° C.	Agar at 37° C.			
1.	2.	3.	4.	5.	
187 Final effluent - - - 12 noon, 3rd Dec. 1900.	116,000	79,000	At least 1,000 -	+ ·1, – ·01 c.c. At least 10 but less than 100.	Second visit, November and December 1900, and January 1901.
188 Final effluent - - - 12.45 p.m., 3rd Dec. 1900.	810,800	67,000	At least 100 - -	+ 1, – ·1 c.c. At least 1 but less than 10.	
189 Final effluent - - - 12.30 p.m., 7th Dec. 1900.	—	—	—	- ditto - ditto.	
190 First field effluent - - 12 noon, 10th Dec. 1900.	13,400,000	2,736,000	At least 100,000 -	+ ·001 c.c. At least 1,000.	
191 Final effluent - - - 1.30 p.m., 10th Dec. 1900.	610,000	13,200	At least 100 - -	+ 1, – ·1 c.c. At least 1 but less than 10.	
192 Final effluent - - - 1 p.m., 11th Dec. 1900.	116,000	2,210	- ditto - -	- ditto - ditto.	
193 First field effluent - - 13th Dec. 1900.	760,000	181,000	At least 10,000 -	+ ·1, – ·01 c.c. At least 10 but less than 100.	
194 Final effluent - - - 13th Dec. 1900.	670,000	10,400	At least 1,000	+ 1, – ·1 c.c. At least 1 but less than 10.	
195 First field effluent - - 11 a.m., 17th Dec. 1900.	178,000	15.900	—	+ ·1 – ·01 c.c. At least 10 but less than 100.	
196 First field effluent - - 12.45 p.m., 19th Dec. 1900.	9,900,000	2,830,000	At least 100,000 -	——	
197 Final effluent - - - 2 p.m., 19th Dec. 1900.	3,790,500	804,000	- ditto - -	——	
198 Final effluent - - - 1.40 p.m., 20th Dec. 1900.	4,310,000	143,000	At least 10,000 -	——	
199 First field effluent - - 2.30 p.m., 2nd Jan. 1901.	15,600,000	3,840,000	At least 100,000 -	+ ·001 c.c. At least 1,000.	
200 Final effluent - - - 3.45 p.m., 2nd Jan. 1901.	5,470,000	960,000	- ditto - -	+ ·01, – ·001 c.c. At least 100 but less than 1,000.	
Averages - - - (Effluents 22 to 200).	3,658,093 [92% reduction]	623,130 [90% reduction]	[Ratio cols. 2 to 3 = 5·8 : 1]		
Averages - - - (Effluents 22 to 180).	2,996,207 [93% reduction]	415,872 [93% reduction]	[Ratio cols. 2 to 3 = 7·2 : 1]		
Averages - - - (Exclusive of the first and second field and experimental effluents.)	778,322 [98% reduction]	35,157 [99% reduction]	[Ratio cols. 2 to 3 = 22 : 1]		

Experimental effluents.

The following is a brief summary of the results shown in Table 14.

Sewage :—

The *total number of bacteria* was over ten million (gelatine at 20°C.), and on the average between one and ten million (agar at 37°C.) per c.c. *B. coli* numbered at least 100,000 per c.c. *B. enteritidis sporogenes* varied in number from 100 to 1,000 per c.c.

Effluents :—

The effluents varied very much in their biological composition.

Total number of bacteria (gelatine at 20°C.) per c.c. :—In four samples the number was over ten million. In twelve samples between one and ten million. In twelve samples between 100,000 and one million. In two samples over 10,000 but less than 100,000. In one sample between 1,000 and 10,000. [Provisional standard, less than 100,000 per c.c.]

Total number of bacteria (agar at 37°C.) per c.c. :—In five samples between one and ten million. In ten samples between 100,000 and one million. In nine samples between 10,000 and 100,000. In six samples between 1,000 and 10,000. In one sample less than 1,000. [Provisional standard, less than 10,000 per c.c.]

B. coli (and closely allied forms) per c.c. :—In eight samples 100,000. In six samples 10,000. In six samples 1,000. In seven samples 100. In three samples 10. [Provisional standard, less than 1,000 per c.c.]

Spores of B. enteritidis sporogenes per c.c. :—In two samples 1,000. In eight samples 100. In nine samples 10. In ten samples 1. In one sample none in 1 c.c. [Provisional standard, less than 10 per c.c.]

The classification of the effluents into ordinary (1st field, 2nd field, final, general) effluents and experimental (1st plot and 2nd plot) effluents, and the different results yielded by these will be considered later on in the report.

2. *Diagram* 9 *illustrating the results shown in Table* 14, *with comments thereon.*

The results are shown in graphic form in Diagram 9.

By referring to Diagram 9 it will be seen that certain horizontal lines are drawn indicating provisional standards (non-drinking water streams).

All samples which, according to these standards, did not fufil the following requirements would be tentatively condemned :—

(1.) Total number of bacteria (gelatine 20° C.). Less than 100,000.
(2.) Total number of bacteria (agar at 37° C.). Less than 10,000.
(3.) B. coli. Less than 1,000 - - - - - -
(4.) B. enteritidis sporogenes. Less than 10 - -

} per c.c.

As regards (1) only 3 out of 31 effluents proved satisfactory.
" " (2) 7 out of 31 effluents passed the standard.
" " (3) 10 out of 30 effluents were satisfactory.
" " (4) 11 out of 30 effluents passed.

In the above summary the 1st and 2nd field and experimental effluents are included. Excluding these, then :—

As regards (1) 3 out of 9 effluents
" " (2) 4 " " "
" " (3) 5 " " "
" " (4) 3 " " "

} "passed" the standards set up for these tests.

As judged by these standards, the majority of the effluents examined proved unsatisfactory.

The variable biological character of the various effluents is striking. Thus, while some were nearly if not quite as impure as raw sewage, others showed a fairly high degree of purification. On the average, and considering all the effluents together, the results were unsatisfactory, although they show that the treatment of sewage by land, even in cases where the land is not very suitable for the purpose, appears to effect a considerable reduction in the total number of bacteria, and the number of B. coli. and of B. enteritidis sporogenes. Excluding all but the final and general effluents, the results were fairly good.

The results show that a broad parallelism exists between the total number of bacteria and the number of B. coli and of B. enteritidis sporogenes present per c.c. in the effluents, but the exceptions to this rule are too frequent to allow of implicit reliance being placed on such a seeming agreement.

The results, judged as a whole, do not lend colour to the belief that land of the kind available at the South Norwood sewage farm could be worked in practice so as uniformly to yield a really good effluent. But as so many of the final and general effluents either passed or came within measurable distance of passing the standards suggested, it may be added that, if an additional area of land could be acquired so as to reduce the existing dose of sewage per acre of land, a majority of the resulting effluents would doubtless be found to be fairly satisfactory.

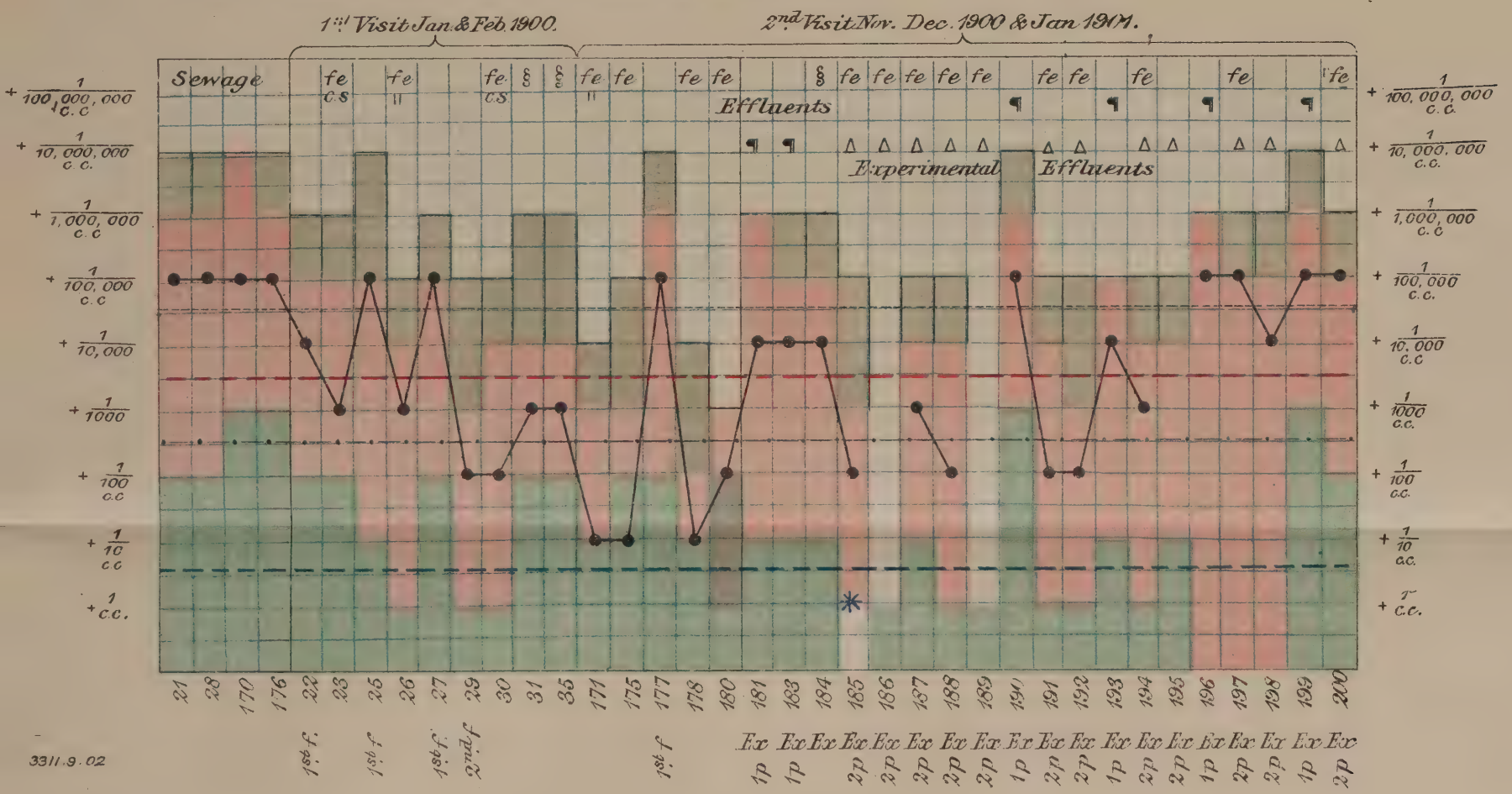
The marked (as a rule) difference between the first field effluents and the finally-treated effluents is well shown in the diagram. It is important to

sewage & of effluents obtained from S. Norwood sewage farm.

= Total number of bacteria (gelatine at 20° c)
= " " " " (agar at 37° c)
B. Coli
B. enteritidis sporogenes

provisional standard ($\frac{1}{100,000}$ c.c.) Three out of Thirty-one effluents passed this standard
" ($\frac{1}{10,000}$ c.c.) Seven " " " " " " " "
" ($\frac{1}{1000}$ c.c.) Ten " " " " " " " "
" ($\frac{1}{10}$ c.c.) Eleven " " " " " " " "

✳ Negative result, 1 c.c. direct (B. enteritidis sporogenes)



1st f = 1st Field effluent
2nd f 2nd " " " "
§ Signifies general effluents
fe " final effluents
Ex " experiments
1p " 1 plot
2p " 2 plots
C.S. " comparative samples
|| " " "
¶ " " "
Δ " " "

3311.9.02

Weller & Graham Ltd Litho. London.

note this point, because it indicates that, given an adequate area of land in relation to the amount of sewage to be treated, it is possible even for land of bad quality to yield satisfactory results.

3. *Results considered in relation to Mr. Kershaw's notes.**

Omitting in the first place a consideration of the experimental effluents, and taking the B. enteritidis sporogenes test as a useful means of gauging the degree of purification effected by the land treatment, it is to be noted that seven [22 (first field effluent), 23, 27 (first field effluent), 31, 35, 175 and 177 (first field effluent)] effluents yielded 100 spores of B. enteritidis sporogenes per c.c., and, therefore, must be regarded as undeniably unsatisfactory. All of these, with the exception of 175, are noted as being either cloudy or having a sewage smell or as being possessed of both these characters. Further, as regards 27, it appears that "the furrows of one of the arable fields ran longitudinally with the flow of the sewage, thus effecting very little purification." 31 and 35 were samples of general effluent, and as regards the former it is noted that the rainfall had largely increased the flow. As regards 175 the bacteriological results judged by other tests were not unsatisfactory.

Turning next to the good effluents, as judged by the B. enteritidis sporogenes test (provisional standard less than 10 per c.c.) it is to be noted that samples 26, 29, 30, and 180 were satisfactory. None of these smelt offensively (with the exception of 180, slight smell) according to Mr. Kershaw's notes, and they also had a longer contact with the soil than some of those previously considered.

Passing next to the experimental effluents 181 to 200, it may be said that the effluents treated over 1 plot (181, 183, 190, 193, 196, 199) were usually worse than the effluents treated over 2 plots (185, 186, 187, 188, 189, 191, 192, 194, 195, 197, 198, 200), which is as might be anticipated. As regards the former, none out of five, in respect of the latter, seven out of ten, effluents passed the B. enteritidis test.

The conditions of the experiment are thus described by Mr. Kershaw :—

"Two arable fields were employed for this experiment (November, 1900), of the areas of 1·25 and 1·0 acres respectively. The land in question had a crop of mangolds during the summer, and had not been sewaged since February, 1900, and no artificial manure had been applied; the plots were freshly ploughed about 8 inches deep two days before commencing the experiment. The sewage was treated twice, being run from the first on to the second plot. The quantity of sewage treated per acre per 24 hours was increased daily from 3,000 gallons the first day by equal increments of 1,500 gallons to 39,000 gallons on the 20th December. The second plot of arable received whatever effluent came off the first plot."

"The sewage was run on to the first plot at noon, November 26th, 3,750 gallons going on to the 1·25 acres."

From this point onwards the reader is referred to Mr. Kershaw's accompanying notes (Addendum C), and it should be specially noted that in connection with sample 195 (17th December, 1900) he remarks that the land was beginning to smell and sewage weed to appear.

As regards the general bacteriological results, it appears that the effluents were at first very bad, later they improved somewhat, although sample 190 (1 plot) was most unsatisfactory; still later, from the time when Mr. Kershaw noticed that the land was beginning to smell until the close of the experiment, the results were undeniably unsatisfactory.

Too much stress must not be laid on the importance of these experimental observations. To be of real use the investigation would need to be modified in a number of ways and extended over a period of some years. But, broadly speaking, the results are of some interest, since they tend to show, as might have been anticipated, that the continuous application of sewage (in the amounts stated) to land of the kind available at South Norwood speedily results in fouling of the land, and in the production of evil odours and objectionable effluents. Nevertheless, considering only the early stages of the experiment, a fair proportion of the 2nd plot effluents were satisfactory. The

*Addendum C, page 117.

marked (as a rule) difference between the 1st and 2nd plot effluents is worth noting, because it tends to show that, given an adequate area of land available for sewage purification purposes, land even of an unsuitable character, can probably effect any reasonable degree of purification.

As regards a classification of the effluents, Mr. Kershaw's notes show that they may be divided into ordinary effluents and experimental effluents. The former may be sub-divided into 1st field, 2nd field, final and general effluents: the latter, into 1st and 2nd plot effluents. All the general, but not the final, effluents included the effluents from the bacteria beds after they had been passed over the land.

For fuller details regarding the various samples, reference must be made to Addendum C.

4.—*Results in relation to tests other than the B. enteritidis sporogenes test.*

So far the records as regards B. enteritidis sporogenes have been chiefly considered, and it is necessary to make a few brief remarks in relation to other tests.

The average number of bacteria in the sewage and effluents is worth noting:

——	Gelatine at 20° C. Microbes per c.c.	Agar at 37° C. Microbes per c.c	Ratio.
Sewage - - - - - - - -	48,600,000	6,357,500	7·6 : 1
Effluents (inclusive of the 1st and 2nd field and experimental effluents).	3,658,093 {92 per cent. reduction.}	633,130 {90 per cent. reduction.}	5·8 : 1
Effluents (exclusive of the 1st and 2nd field and experimental effluents).	778,322 {98 per cent. reduction.}	35,197 {99 per cent. reduction.}	22 : 1

Although the figures undoubtedly represent a high *percentage* degree of purification, the *actual* number of microbes remaining even in the final effluents is so great that mere percentage reduction must not be regarded as of too much importance. Moreover, the number of samples of finally treated effluents was not sufficiently numerous to make these average figures absolutely reliable.

It might perhaps have been hoped that, even if the total number of bacteria was not reduced to a satisfactory extent, at all events the ratio of the number of bacteria growing in agar at 37° C., as compared with those growing in gelatine at 20° C., would be altered in the right direction. The opposite, however, was found to be the case when the good, bad, and indifferent effluents were all classed together, the ratio in the case of the sewage being 1 : 7·6, and as regards the effluents 1 : 5·8. Nevertheless, when the 1st and 2nd field and experimental effluents are excluded, the final and general effluents do indeed show a greater *proportionate* reduction in the microbes capable of growing at blood heat than in the bacteria growing in gelatine at 20° C. The figures being 1 of the former to 22 of the latter.

Reverting once more to the average figures (exclusive of the 1st and 2nd field and experimental effluents), namely, about 780,000 (gelatine at 20° C.), and about 35,000 (agar at 37° C.) bacteria per c.c., the results do not, perhaps, indicate that land of the kind available at South Norwood could be worked in practice so as uniformly to yield effluents passing the standards of less than 100,000 or 10,000 microbes, respectively, per c.c.; but these results certainly show that even surface irrigation over clay land can effect a remarkable percentage purification of sewage, and an actual purification coming within measurable distance of passing the suggested standards.

About one-third of the total number of effluents passed, and a number of others came within measurable distance of passing, the B. coli as well as the B. enteritidis sporogenes standards. As regards the final and general effluents (*i.e.*, excluding the experimental and partially tested effluents), the

results as regards the B. coli test were decidedly good, as all the effluents either passed or came near passing the standard set up for this test.

In the Table and Diagram, illustrating Appendix III. (page 196) the results as regards the "gas" and B. enteritidis sporogenes tests are brought into comparison Out of 21 samples of effluents of all kinds, five passed the "gas" test and nine the B. enteritidis sporogenes test. In addition, nine samples came within measurable distance of passing the former and eight samples the latter test.

Indol test. (Indol in broth cultures, five days at 37° C.) :—

The following results were obtained by the use of this test :

Samples of sewage 28,170 and 176 all gave a positive result with ·00001 c.c.

Effluents 25, 28, 177, 181, 190, 196, 197, 199, 200 gave a positive result with ·00001 c.c

Effluents 26, 27, 183, 184, 193, 198, a positive result with ·0001 c.c.
,, 31, 35, 180, 187 ,, ,, ,, ·001 c.c.
,, 178, 185, 188, 191 ,, ,, ,, ·01 c.c.
,, 171, 175, 192, 194 ,, ,, ,, ·1 c.c.
,, 29 and 30 a negative result with ·001 c.c.

These figures run broadly parallel with the B. coli results. The standard suggested for effluents discharging into non-drinking water streams is a negative result with ·001 c.c. Ten out of 29 effluents of all kinds passed this standard. Excluding the experimental and partially treated effluents, about one-half of the effluents were satisfactory on the basis of this test.

5. *Results of the bacteriological examination of additional samples of brook water, mixture of brook water and effluent, and samples of street "washings."*

In Table 15 the results of the examination of these samples are shown.

TABLE 15.—Showing the results of the bacteriological examination of samples of brook water, street water, etc., obtained from South Norwood Sewage Farm.

Description of the Sample.	Total Number of bacteria per c.c.		Number of B. coli (or closely allied forms) per c.c.	Number of Spores of B. enteritidis sporogenes (Kleins "enteritidis change" in milk culture) per c.c.
	Gelatine at 20° C.	Agar at 37° C.		
31 Combined effluents (rate of flow 1½ million gallons per 24 hours). 30/1/00.	1,620,000	83,000	1,000 not 10,000 - (Indol + ·001 c.c.)	·01, – ·001 c.c. 100 but less than 1,000.
32 Chaffinch Brook above junction with effluents (rate of flow about 500,000 gallons per 24 hours). 30/1/00.	7,900	1,100	100 not 1,000 - (Indol + ·01 c.c.)	+ 10 c.c., – 1 c.c. None in 1 c.c.
33 Chaffinch Brook water and effluent (20 yards below the effluent outfall). 30/1/00.	103,000	11,900	At least 1,000 - (Indol + ·001 c.c.)	+ ·1, – ·01 c.c. At least 10 but less than 100.
34 Same lower down (466 yards below 33). 30/1/00.	470,000	12,400	1,000 not 10,000 - (Indol + ·001 c.c.)	+ ·01 c.c. At least 100.
174 Brook (represents street "washings"). 14/11/00.	1,470,000	88,000	At least 10 - - (Indol + ·1 c.c.)	+ ·01, – ·001 c.c. At least 100 but less than 1,000.
179 Surface water from streets 21/11/00.	3,840,000	293,000	10,000 not 100,000 - (Indol + ·00001 c.c.)	+ ·1, – ·01 c.c. At least 10 but less than 100.
182 Street water after running 2 hours. 28/11/00.	13,700,000	154,000	10,000 - - (Indol + ·0001 c.c.)	+ ·01, – ·001 c.c. At least 100 but less than 1,000.
188B Street "washings" after running 4 hours. 1/12/00.	9,900,000	380,000	1,000 - - - (Indol + ·001 c.c.)	ditto ditto.

At time of collection, ratio of brook water to effluent about 1 to 3.

Samples 174, 179, 188B yielded the following results as regards the "gas" test ("gas" in gelatine "shake cultures in 24 hours at 20°C.) :—+ ·1, – ·01 c.c. ; + ·01 c.c. ; + ·1, – ·01 c.c., respectively.

Two guinea-pigs (*a*, *b*) were subcutaneously inoculated with 1c.c. (*a*) and 2c.c. (*b*) of sample 188B.

(*a*) Guinea-pig developed a big swelling at the site of the inoculation, but eventually recovered completely.

(*b*) Guinea-pig died on the second day.

The brook water (32) above (about 20 yards) the point of discharge into it of the effluent was by no means a pure water, although not nearly so impure as the effluent (31).

The mixed brook water and effluent (33) collected about 20 yards below the effluent outfall was purer than the effluent (31) and much more impure than the brook water alone (32). The sample (34) collected lower down (about 466 yards below 33) the brook was, curiously enough, less satisfactory than the one collected higher up (33). Assuming no serious contamination between the two points of collection, this would seem to indicate that flowing the distance of about a quarter of a mile would not sensibly improve the biological condition of a polluted river water. But from the bacteriological point of view, small importance attaches to these isolated observations, although, from the chemical stand-point, they may yield results of considerable value. At the time of the collection the volume of effluent *exceeded* the volume of river water.

Of far greater interest are the results of the examination of the samples (174, 179, 182, 188B) of street "washings." All the samples were very impure and, indeed, did not differ to any great extent in their biological composition from samples of dilute sewage. 2 c.c. of sample 188B injected subcutaneously into a guinea-pig, killed the animal within two days.

The grossly impure character, from the bacteriological point of view, of these samples, representative of street "washings," is a point which must not be overlooked in the future.

6. *General conclusions.**

The results as a whole were not altogether satisfactory, but the finally-treated effluents were by no means so unsatisfactory as to prove that land of the kind available at South Norwood could not possibly be worked so as uniformly to yield a *fairly* good effluent. In order to effect this an additional area of land would be required, which may seem an impracticable suggestion; but it needs to be remembered that the extra area of land assumed to be necessary, where the land available is of either distinctly unsuitable or in a less degree ill-suited adequately to treat sewage, has probably been greatly under, not over, estimated in the past.

The general results are of an encouraging nature, inasmuch as they clearly show that even clay land can be worked so as to yield final effluents which, as compared with the crude sewage, show a remarkable degree of percentage purification and an actual purification by no means of a low order.

Considered from the bacteriological point of view, none of the effluents were in a fit state to be turned into a drinking-water stream.

Addendum A.—*Comparative records as regards (a) the "gas" and (b), B. enteritidis sporogenes tests of samples obtained from South Norwood as well as other sewage farms.*

These results are shown in the Table and Diagram, illustrating Appendix III. (page 196), and they include all the samples (from other sewage farms besides South Norwood) which were examined by both of the tests.

As regards the "gas" test, five samples passed and ten additional samples came within measurable distance of passing the standard suggested, viz., a negative result with 0·1 c.c., out of a total of 21 samples.

As regards the B. enteritidis sporogenes test, out of a total of 21 samples nine samples passed and eight additional samples came within measurable distance of passing the standard suggested, viz., a negative result with 0·1 c.c

Excluding the partially-treated and experimental effluents, two out of five and three out of five samples of effluent, respectively, passed the standards set up for the above tests.

---

* For statistical information see tabular statement at the beginning of this Report, Section VI.

Addendum B.—*Additional bacteriological notes.*

Streptococci (surface agar plate cultures at 37° C.) :—

Streptococcus 4 was isolated from ·001 c.c. crude sewage 21.
" 5 " " " ·01 c.c. effluent 22.
" 6 " " " ·01 c.c. " 23.

Streptococci 15 and 16 were isolated from ·001 c.c. sewage 176.

Streptococcus 1 was isolated from ·01 c.c. effluent 177.

No streptococci could be found in ·1 c.c. effluent 178.

The following is a brief description of the morphological and biological characters of the streptococci above referred to :—

Streptococcus 4.—Isolated from ·001 c.c. sewage 21 (surface agar plate cultures at 37° C.)

Morphology.—Stains well by Gram's method. Unquestionably a streptococcus. Chains short.

Agar (37° C.) *and gelatine* (20° C.) *plate cultures.*—Minute, slow-growing, transparent-looking colonies. Observed under a low power of the microscope, colonies faintly granular in appearance with a *clean* edge, no loops of cocci visible at the periphery.

Gelatine "streak" cultures (20° C.)—Minute, transparent-looking colonies. No liquefaction.

Broth cultures (37° C.)—Uniform turbidity.

Litmus milk cultures (37° C.)—Fairly strong acid but no clot.

Remarks.—Non-pathogenic to mice.

Streptococcus 5.—Isolated from ·01 c.c. effluent 22 (surface agar plate cultures at 37° C.).

Morphology.—Stains well by Gram's method. Unquestionably a streptococcus. Short chains, but longer than streptococcus 4 (*see* Plate III., Fig. 7).

Agar (37° C.) *and gelatine* (20° C.) *plate cultures.*—Resembles streptococcus 4, but colonies even more minute, slow-growing and transparent-looking.

Gelatine "streak" cultures (20° C.)—Resembles streptococcus 4, but colonies even more minute.

Broth cultures (37° C.)—Diffuse but not very abundant cloudiness. Deposit at the foot of the tube somewhat granular in character.

Litmus milk cultures (37° C.)—Fairly strong acid but no clot.

Remarks.—Non-pathogenic to mice.

Streptococcus 6.—Isolated from ·01 c.c. effluent 23 (surface agar plate cultures at 37° C.).

Morphology.—Stains well by Gram's method. Unquestionably a streptococcus. Short to medium chains, longer than streptococcus 5 on the average (*see* Plate III., Fig. 8.)

Agar (37° C.) *and gelatine* (20° C.) *plate cultures.*—Resembles streptococcus 4 very closely.

Gelatine "streak" cultures (20° C.)—Resembles streptococcus 4 very closely.

Broth cultures (37° C.)—Mixture of diffuse and granular cloudiness; at foot of tube granular-looking deposit.

Litmus milk cultures (37° C.)—Fairly strong acid but no clot.

Remarks.—Non-pathogenic to mice.

Streptococcus 15.—Isolated from ·001 c.c. sewage 176 (surface agar plate cultures at 37° C.).

Morphology.—Stains well by Gram's method. Chains short to medium. Involution forms well marked; many of the elements oval in shape and swollen-looking. Bacillary forms numerous (*see* Plate III., Fig. 9).

Gelatine "streak" cultures (20° C.)—Minute, transparent-looking colonies. No liquefaction.

Broth cultures (37° C.)—Diffuse cloudiness.

Litmus milk cultures (37° C.)—Fairly strong acid but no clot.

Remarks.—Non-pathogenic to mice.

Streptococcus 16.—Isolated from ·001 c.c. sewage 176 (surface agar plate culture at 37° C.).

Morphology.—Stains well by Gram's method. Chains of medium length. Involution forms well marked (*see* Plate III., Figs. 10 and 11).

Gelatine "streak" cultures (20° C.).—Minute, transparent-looking, slowly-growing colonies. No liquefaction.

Broth cultures (37° C.)—Slight granular cloudiness at foot of tube; viscous, stringy growth.

Litmus milk cultures (37° C.)—Little or no visible change.

Remarks.—Non-pathogenic to mice.

[? *Streptococcus* 17].—Isolated from ·01 c.c. effluent 177 (surface agar plate cultures at 37° C.).

Morphology.—Stains well by Gram's method. Chains of irregularly-shaped cocci (?) aggregated together to form coherent masses (*see* Plate III., Fig. 12.)

Gelatine (20° C.) *and agar* (37° C.) *"streak" cultures.*—The growth resembles that of a streptococcus.

Broth cultures (37° C.)—The broth remains transparent; at the foot of the tube a few small granular masses may be seen. Later these combine to form one or more large coherent masses.

Litmus milk cultures (37° C.).—Acidity but no clot.

Remarks.—Identity with the streptococcus class somewhat doubtful.

Animal inoculation experiments.—These are dealt with in a separate report on the subject, but it may not be amiss again to record them as briefly as possible.

South Norwood street washings, after running four hours, 5th December 1900.—Two guinea-pigs were inoculated subcutaneously, the one (A) with 1 c.c., the other (B) with 2 c.c of the sample. Although (A) guinea-pig eventually recovered it developed a big swelling and was ill for some days. (B) guinea-pig died on the second day.

South Norwood settled sewage (samples A, D, G), collected on 10th, 11th, and 12th September 1901.—In each case a guinea-pig was inoculated subcutaneously with 3 c.c. of the sample, and death resulted within 24 hours.

South Norwood 1st field effluents (samples B and E), collected on 10th and 11th December 1901.—Two guinea-pigs were respectively inoculated subcutaneously, one with 3 c.c. and the other with 6 c.c. of each sample. The two "sample (B) guinea-pigs" died within three days, and the two "sample (E) guinea-pigs" within two days.

South Norwood Sewage Farm, 20th November, 1900.—Two guinea-pigs were inoculated subcutaneously, the one (A) with 1 c.c. of *settled sewage* 176, the other (B) with 4 c.c. of *final effluent* 178. (A) guinea-pig had a slight swelling at the site of the inoculation, but otherwise remained unaffected. (B) guinea-pig showed little or no reaction.

South Norwood 1st field effluent (H), collected during rainy weather, 12th September, 1901.—In this experiment guinea-pigs inoculated with 3 c.c. and 6 c.c. respectively of the sample recovered.

South Norwood final effluents (C, F, and I), collected respectively on 10th, 11th, and 12th September, 1901.—In each case two guinea-pigs were inoculated, one with 3 c.c. and the other with 6 c.c. of the sample. The animals, however, all recovered from the effects of the injections.

South Norwood settled sewage (sample D), 11th September, 1901.—Some of the sewage *was heated to* 80° *C. for ten minutes*, and then 5 c.c. were injected subcutaneously into a guinea-pig. The animal recovered.

South Norwood settled sewage (sample G), 12th September, 1901.—Same conditions of experiment as in the previous experiment, but here the animal succumbed on the second day.

South Norwood settled sewage (samples A, D, G), collected on 10th, 11th and 12th September, 1901. The sewage in each case *was heated to* 100° C. *for* 1 *hour* and guinea-pigs severally inoculated subcutaneously with 10 c.c. of the samples. The result was negative.

South Norwood settled sewage (samples A, D, G, J), collected on 10th, 11th, 12th, and 18th September, 1901.—The sewage in each case was *filtered through a sterilised Pasteur's filter* and 20 c.c. *of the filtrate* injected subcutaneously into rodents. The result was negative in each case.

South Norwood effluent from 1st field, 10th September, 1901 (sample B)—3 c.c. of the effluent were injected subcutaneously into a guinea-pig. The animal died on the third day, and from its heart's blood *a pure culture of B. pyocaneus was obtained.*

PLATE III.

Fig. 7. Streptococcus 5. Microscopic preparation from a broth culture (24 hours at 37° C.)—Stained by Gram's method.

[Magnifying power, 1,000.]

Fig. 8. Streptococcus 6. Microscopic preparation from a broth culture (24 hours at 37° C.)—Stained by Gram's method.

[Magnifying power, 1,000.]

Fig. 9. Streptococcus 15. Microscopic preparation from a broth culture (24 hours at 37° C.)—Stained by Gram's method.

[Magnifying power, 1,000.]

Fig. 10. Streptococcus 16. Microscopic preparation from a broth culture (48 hours at 37° C.)—Stained by Gram's method.

[Magnifying power, 500.]

Fig. 11. The same as figure 10, but a higher magnification.

[Magnifying power, 1,000.]

Fig. 12. [? Streptococcus 17.] Microscopic preparation from an agar culture (24 hours at 37° C.)—Stained by Gram's method.

[Magnifying power, 1,000.]

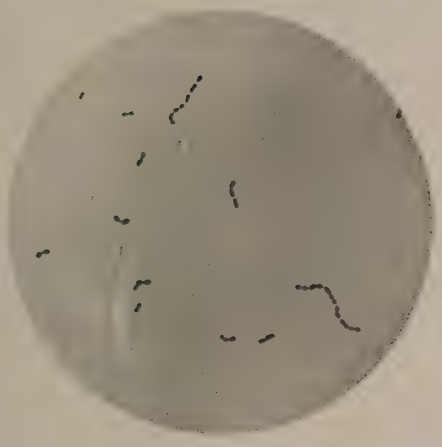


Fig. 7.

Fig. 8.

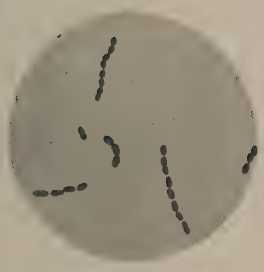


Fig. 9.

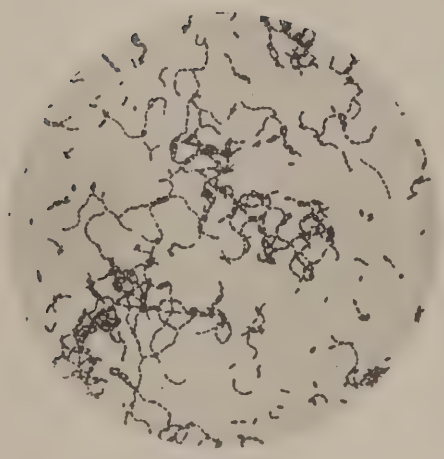


Fig. 10.

Fig. 11.

Fig. 12.

ADDENDUM C.—*Mr. Kershaw's abridged notes to accompany the bacteriological data.*

SOUTH NORWOOD SEWAGE FARM.

(DOMESTIC SEWAGE.)

Number of Sample	Date of drawing Sample.	Time of day.	Rainfall day previous to drawing Sample.	Rainfall day of drawing Sample.	Air temperature time of drawing Sample.	Temperature of Sample.	Maximum temperature during the 24 hours.	Minimum temperature during the 24 hours.	Humidity (9 a.m.)	Dissolved oxygen in Sample.	Brief description of Sample.	REMARKS.
	1900:		Inches.	Inches.	°C. °F.	°C. °F.	°C. °F.	°C. °F.		c.c.		
21	9 January	2.15 p.m.	·07	·01	—	7·7 (46)	9·4 (49)	4·4 (40)	—	—	Screened and settled sewage.	*Mean daily maximum temperature, 6·9 °C. (44·5 °F.) Mean daily minimum temperature, 1·4 °C. (34·5 °F.) Mean daily rainfall, ·06 inch.
22	9 "	3.15 "	·07	01	—	6·1 (43)	9·4 (49)	4·4 (40)	—	—	First field effluent.	
23	9 "	5.15 ,	·07	·01	—	4·4 (40)	9·4 (49)	4·4 (40)	—	—	Final effluent.	
24	16 "	1 "	·18	·28	—	7·7 (46)	6·1 (43)	2·7 (37)	—	—	Screened and settled sewage.	*For the period 8th January to 30th January 1900.
25	16 "	2 "	·18	·28	—	6·6 (44)	6·1 (43)	2·7 (37)	—	—	First field effluent.	
26	16 "	3 "	·18	·28	—	5·0 (41)	6·1 (43)	2·7 (37)	—	—	Final effluent.	
27	16 "	2.45 "	·18	·28	—	6·6 (44)	6·1 (43)	2·7 (37)	—	—	First field effluent.	*Note.*—Samples which may have been affected by rainfall are underlined.
28	22 "	2.45 "	·00	·17	—	7·7 (46)	8·3 (47)	1·6 (35)	—	—	Screened and settled sewage.	
29	22 ,	4 "	·00	·17	—	6·6 (44)	8·3 (47)	1·6 (35)	—	—	Second field effluent.	
30	22 "	4.45 "	·00	·17	—	7·2 (45)	8·3 (57)	1·6 (35)	—	—	Final effluent.	
31	30 "	4 "	·24 (S.R.)†	·03	—	3·3 (38)	3·8 (39)	3·3 (38)	—	—	§General effluent.	†S.R. signifies snow and rain.
32	30 ,	4.45 "	·24 (S.R.)	·03	—	3·8 (39)	3·8 (39)	3·3 (38)	—	—	Brook water.	§By "general" effluent is meant a mixture of two or more finally treated effluents on leaving the farm.
33	30 "	5 "	·24 (S.R.)	·03	—	3·8 (39)	3·8 (39)	3·3 (38)	—	—	Brook water and effluent.	
34	30 "	5.30 "	·24 (S.R.)	·03	—	3·8 (39)	3·8 (39)	3·3 (38)	—	—	" " " "	
35	29 "	3.30 "	·11 (S.R.)	·24 (S.R.)	—	3·3 (38)	3·3 (38)	0·0 (32)	—	—	General effluent.	
35a	5 February	12.45 "	—	—	—	2·7 (37)	—	—	—	—	" "	
170	7 November	12 (noon)	·015	·18	10·0 (50)	12·7 (55)	13·8 (57)	7·7 (46)	86	—	Crude sewage.	*Mean daily maximum temperature, 10·1 °C. (50·3 °F.) Mean daily minimum temperature, 2·9 °C. (37·3 °F.) Mean daily rainfall, ·087 ins.
171	7 "	2.30 p.m.	·015	·18	9·4 (49)	10·0 (50)	13·8 (57)	7·7 (46)	86	3·0	Final effluent.	
174	14 "	2.15 "	·08	·08	10·5 (51)	10·5 (51)	13·8 (57)	4·4 (40)	86	1·25	Street washings.	

SOUTH NORWOOD SEWAGE FARM.—Domestic Sewage—*continued.*

Number of Sample.	Date of drawing Sample.	Time of day.	Rainfall day previous to drawing Sample.	Rainfall day of drawing Sample.	Air temperature time of drawing Sample.	Temperature of Sample.	Maximum temperature during the 24 hours.	Minimum temperature during the 24 hours.	Humidity (9 a.m.)	Dissolved oxygen in Sample.	Brief description of Sample.	REMARKS.
	1900:		Inches.	Inches.	°C. °F.	°C. °F.	°C. °F.	°C. °F.		c.c.		
175	14 November	2.45 „	·08	·08	10·5 (51)	8·8 (48)	13·8 (57)	4·4 (40)	86	0·3	Final effluent.	Mean daily humidity, 82·7.
176	20 „	12 (noon)	·00	·05	6·6 (44)	11·1 (52)	9·4 (49)	0·5 (33)	92	—	Screened and settled sewage.	*For the period 7th November to 25th November, 1900.
177	20 „	1 p.m.	·00	·05	7·2 (45)	9·4 (49)	9·4 (49)	0·5 (33)	92	0·25	First field effluent.	
178	20 „	3 „	·00	·05	7·2 (45)	6·6 (44)	9·4 (49)	0·5 (33)	92	2·0	Final effluent.	
179	21 „	1 „	·05	·02	8·3 (47)	8·3 (47)	6·6 (44)	4·4 (40)	86	—	Street washings.	
180	21 „	1.45 „	·05	·02	7·7 (46)	7·2 (45)	6·6 (44)	4·4 (40)	86	2·0	Final effluent.	
180b	23 „	1 p.m.	·00	·00	7·2 (45)	7·2 (45)	10·5 (51)	8·8 (48)	74	3·50	Brook water and effluent.	
180a	23 „	1. 5 „	·00	·00	7·2 (45)	6·6 (44)	10·5 (51)	8·8 (48)	74	—	Final effluent.	
	1900:				EXPERIMENT.							
181	27 November	2. 5 „	·00	·03	12·2 (54)	8·8 (48)	11·6 (53)	2·7 (37)	85	1·0	First field effluent.	
181a	27 „	1	·00	·03	10·5 (51)	11·1 (52)	11·6 (53)	2·7 (37)	85	—	Screened and settled sewage.	
182	28 „	12.45 „	·03	·08	8·8 (48)	9·4 (49)	12·2 (54)	– 1·1 (30)	98	—	Street washings.	
183	28 „	1.30 „	·03	·08	8·8 (48)	7·7 (46)	12·2 (54)	– 1·1 (30)	98	1·0	First field effluent.	
184	28 „	2.15 „	·03	·08	9·4 (49)	7·7 (46)	12·2 (54)	– 1·1 (30)	98	0·50	General effluent.	
185a	29 „	1 „	·08	·13	8·3 (47)	7·7 (46)	7·7 (46)	3·8 (39)	98	2·0	First field effluent.	
185	29 „	2.45 „	·08	·13	8·3 (47)	7·2 (45)	7·7 (46)	3·8 (39)	98	4·0	Final effluent.	
186a	30 „	11.30 a.m.	·13	·01	8·3 (47)	7·7 (46)	7·7 (46)	2·2 (36)	76	3·0	First field effluent.	Mean daily maximum temperature, 10·8° C. (51·5 °F.).
186	30 „	11.40 „	·13	·01	8·3 (47)	7·2 (45)	7·7 (46)	2·2 (36)	76	1·0	Final effluent.	Mean daily minimum temperature, 4·2° C. (39·6 °F.).
187a	1 December	11.15 „	·01	·04	8·3 (47)	7·7 (46)	7·7 (46)	4·4 (40)	96	—	Street washings.	Mean daily rainfall, ·063 ins.
187b	1 „	11.30 „	·01	·04	8·3 (47)	7·7 (46)	7·7 (46)	4·4 (40)	93	—	First field effluent.	Mean daily humidity, 88.

[illegible]	7 December	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Final effluent.	For the period 26th November to 20th December, 1900.
187d	3 „	11.45 a.m.	·01	·00	6·6	(44)	7·2	(45)	6·6	(44)	2·7	(37)	92	0·50	First field effluent.	
187	3 „	12 noon	·01	·00	6·6	(44)	6·6	(44)	6·6	(44)	2·7	(37)	92	0·50	Final effluent.	
188b	5 „	11 a.m.	·05	·20	15·5	(60)	9·4	(49)	17·7	(64)	8·8	(48)	96	—	Street washings.	
188a	5 „	11.30 „	·05	·20	15·5	(60)	9·4	(49)	17·7	(64)	8·8	(48)	96	—	First field effluent.	
188	5 „	12.45 p.m.	·05	·20	15·5	(60)	9·4	(49)	17·7	(64)	8·8	(48)	96	—	Final effluent.	
189a	7 December	11 a.m.	·136	·14	9·4	(49)	8·3	(47)	11·1	(52)	3·8	(39)	86	0·25	First field effluent.	
189	7 „	12.30 p.m.	·136	·14	9·4	(49)	7·2	(45)	11·1	(52)	3·8	(39)	86	—	Final effluent.	
189b	8 „	11 a.m.	·14	·02	—		—		10·0	(50)	−1·1	(30)	93	0·25	First field effluent.	
189c	8 „	12.40 p.m.	·14	·02	11·1	(52)	8·3	(47)	10·0	(50)	−1·1	(30)	93	2·0	Final effluent.	
190	10 „	12 (noon)	·01	·01	9·4	(49)	7·7	(46)	11·6	(53)	2·2	(36)	86	—	First field effluent.	
191	10 „	1.30 p.m.	·01	·01	10·0	(50)	6·6	(44)	11·6	(53)	2·2	(36)	86	1·50	Final effluent.	
191a	11 „	11.20 a.m.	·01	·00	9·4	(49)	8·3	(47)	10·5	(51)	−1·6	(29)	93	0·50	First field effluent	
192	11 „	1 p.m.	·01	·00	10·0	(50)	7·2	(45)	10·5	(51)	−1·6	(29)	93	1·75	Final effluent.	
193a	13 „	11 a.m.	·00	·15	10·0	(50)	11·1	(52)	12·7	(55)	9·4	(49)	93	—	Screened and settled sewage.	
193	13 „	12 (noon)	·00	·15	10·0	(50)	9·4	(49)	12·7	(55)	9·4	(49)	93	—	First field effluent.	
194	13 „	1 p.m.	·00	·15	10·5	(51)	10·0	(50)	12·7	(55)	9·4	(49)	93	—	Final effluent.	
194a	14 „	10.30 a.m.	·15	·03	10·0	(50)	8·3	(47)	10·0	(50)	3·8	(39)	79	—	First field effluent.	
194b	14 „	11.30 „	·15	·03	10·5	(51)	6·1	(43)	10·0	(50)	3·8	(39)	79	—	Final effluent.	
194c	15 „	10.45 a.m.	·03	·01	10·5	(51)	9·4	(49)	11·6	(58)	8·8	(48)	93	—	First field effluent.	
194d	15 „	11.45 „	·03	·01	10·5	(51)	9·4	(49)	11·6	(58)	8·8	(48)	93	—	Final effluent.	
195	17 „	11 „	·00	·00	8·3	(47)	7·2	(45)	11·1	(52)	5·5	(42)	86	1·50	First field effluent.	
195a	17	12 (noon)	·00	·00	8·3	(47)	7·7	(46)	11·1	(52)	5·5	(42)	86	0·0	Final effluent.	
196	19 „	12.15 p.m.	·00	·30	7·2	(45)	8·3	(47)	10·0	(50)	1·6	(35)	95	0·0	First field effluent.	
197	19 „	2 „	·00	·30	6·6	(44)	7·2	(45)	10·0	(50)	1·6	(35)	95	0·0	Final effluent.	
197a	20 „	12.40 „	·30	·01	10·0	(50)	8·8	(48)	10·5	(51)	5·0	(41)	86	0·0	First field effluent.	
198	20 „	1.40 „	·30	·01	10·5	(51)	8·8	(48)	10·5	(51)	5·0	(41)	86	0·0	Final effluent.	
99	1901: January	2.30	·01	·00	3·3	(38)	6·1	(43)	6·6	(44)	2·2	(36)	86	0·0	First field effluent.	
200	2 „	3.45	·01	·00	3·8	(39)	5·0	(41)	6·6	(44)	2·2	(36)	86	0·0	Final effluent.	

END OF EXPERIMENT.

SOUTH NORWOOD SEWAGE FARM.

(Domestic Sewage.)

Number of Sample.	Number of times the sewage was passed through or over the soil.	Area of plot or plots sewaged at the time of drawing Sample.	Length of time those plots had been sewaged previously to drawing Sample.	Nature of crops grown on plots.	Remarks.
		Acres.	Days.		
22	Once.	6·5	3 continuously.	Ryegrass - - -	Cloudy appearance, sewage smell.
23	Three times.	1·3 1·0	3 continuously.	„ - - -	Slightly cloudy, very slight sewage smell.
25	Once.	3·80	2 continuously.	„ - - -	Cloudy, slight sewage smell.
26	Twice.	4·40	2 continuously.	„ - - -	Fairly clear, no smell.
27	Once.	6·50	2 continuously.	Arable - - -	Effluent rather cloudy.
29	Twice.	3·40 1·30	2 continuously.	Ryegrass - -	Opalescent effluent no smell.
30	Three times.	2·30	2 continuously.	„ - - -	Fairly clear.
31	General effluent - - - - - - - - - - - -				„ yellowish colour.
32	Water from Chaffinch Brook taken 20 yards above effluent outfall -				Rather turbid.
33	Water from Chaffinch Brook taken 20 yards below effluent outfall -				„ „ yellowish colour.
34	Water from Chaffinch Brook taken 466 yards below No. 33 - - -				„ „ „ „
35	General effluent - - - - - - - - - - - -				Rather cloudy.
171	Twice.	3·80 4·40	2 continuously.	Ryegrass - - -	Clear, no smell.
175	Four times.	3·60, 1·30, 1·0, 1·75, Arable.	4	Rye and arable -	„ „
177	Once.	3·40	3	Ryegrass - - -	Strong sewage smell.
178	Three times.	2·40 1·70	3	„ - - -	Slight „ „
180	„	3·50, 1·25, 1·0	3	„ - - -	Slight smell, yellowish colour.
180a	„	3·40, 1·30, 2·	2	„ - - -	„ yellow colour.
			Experiment.		
181	Once.	0·25	1	Arable - - - -	Surface effluent, cloudy.
183	„	0·32	2	„ - - - -	„ „ rather cloudy.
184	—	—	—	—	General effluent, cloudy, no smell.
185a	Once.	0·40	3	„ - - - -	Surface effluent, fairly clear.
185	Twice.	0·4 + 0·1	2	„ - - - -	„ „ clear, no smell.
186a	Once.	0·46	4	„ - - - -	Surface effluent, fairly clear, no smell.
186	Twice.	0·46 + 0·12	3	„ - - - -	Surface effluent, no smell, clear.
187b	Once	0·55	5	„ - - - -	Surface effluent, fairly clear.
187c	Twice	0·55 + 0·18	4	„ - - - -	„ „ „ clear, no smell.
187d	Once	0·70	7	„ - - - -	Surface effluent, yellow colour slight sewage smell.
187	Twice	0·70 + 0·20	6	„ - - - -	Surface effluent, suspended matter
188a	Once	0·80	9	„ - - - -	„ „ sewage smell.
188	Twice	0·80 + 0·24	8	„ - - - -	„ „ slight sewage smell, rather cloudy.
189a	Once	0·88	11	„ - - - -	Surface effluent, slight sewage smell, cloudy.
189	Twice	0·88 + 0·30	10	„ - - - -	Surface effluent, slight sewage smell, greenish-yellow colour

SOUTH NORWOOD SEWAGE FARM.—Domestic Sewage—*continued.*

Number of Sample.	Number of times the sewage was passed through or over the soil.	Area of plot or plots sewaged at the time of drawing Sample.	Length of time those plots had been sewaged previously to drawing Sample.	Nature of crops grown on plots.	Remarks.
		Acres.	Days.		
189b	Once	1·25	12	Arable - - - -	Surface effluent, strong sewage smell, cloudy, suspended matter.
189c	Twice	1+0·36	11	„ - - - -	Surface effluent, slight sewage smell, yellow colour.
190	Once	1·16	14	„ - - - -	Surface effluent, sewage smell, cloudy.
191	Twice	1·16+0·38	13	„ - - -	Surface effluent, slight smell, clear.
191a	Once	1·18	15	„ - - - -	Surface effluent, sewage smell, fairly clear, yellow colour.
192	Twice	1·18+0·42	14	„ - - - -	Surface effluent, clear, yellow colour, slight sewage smell.
193	Once	1·20	17	„ - - - -	Surface effluent, sewage smell, cloudy.
194	Twice	1·20+0·50	16	„ - - - -	Surface effluent, rather cloudy, slight smell.
194a	Once	1·20	18	„ - - - -	Surface effluent, cloudy, sewage smell.
194b	Twice	1·20+0·55	17	„ - - - -	Surface effluent, clear, yellow colour, slight smell.
194c	Once	1·25	19	„ - - - -	Surface effluent, cloudy, sewage smell.
194d	Twice	1·25+0·58	18	„ - - - -	Surface effluent, suspended matter, cloudy.
195a	Once	1·25	21	„ - - - -	Surface effluent, putrid smell, cloudy.
195	Twice	1·25+0·58	20	„ - - - -	Surface effluent, slightly cloudy, no smell.
196	Once	1·25	23	„ - - - -	Surface effluent, strong sewage smell, cloudy.
197	Twice	1·25+0·60	22	„ - - - -	Surface effluent, turbid, sewage smell.
197a	Once	1·25	24	„ - - - -	Surface effluent, strong sewage smell, cloudy.
198	Twice	1·25+0·70	23	„ - - - -	Surface effluent, sewage smell, yellow colour.
199	Once	1·25	37	„ - - - -	Surface effluent, very foul effluent.
200	Twice	1·25+0·80	36	„ - - - -	Surface effluent, strong sewage smell.

SOUTH NORWOOD SEWAGE FARM.

(Domestic Sewage.)

ADDITIONAL NOTES ON SAMPLES.*

Sample No. 27.—In this case the furrows of one of the arable fields ran longitudinally with the flow of the sewage, thus effecting very little purification.

Sample No. 31.—The general effluent was flowing at the time of sampling at the rate of about 1½ million gallons per 24 hours, the rainfall had largely increased the flow.

Sample No. 32.—The Chaffinch Beck was flowing a good deal above the normal flow owing to recent rains. Rate of flow about 500,000 gallons per 24 hours, or in the proportion of one of stream water to three of effluent. The stream did not appear to be in very good condition. This sample was drawn 20 yards above the point where the effluent discharges into the stream.

Sample No. 33.—This sample was drawn 20 yards below the effluent outfall. Some sewage weed below the effluent outfall at the sides of the stream.

Sample No. 34.—This sample was taken 466 yards below sample No. 33; no sewage weed observable.

Sample No. 175.—The sewage from which this effluent was obtained was treated over four separate plots.

Sample No. 174.—Surface water from streets and front roofs, turbid, taken after sharp showers the day previous, and also whilst drawing the sample.

Sample No. 179.—Surface water from streets after moderate showers; streets washed fairly clean by previous rainfall.

Sample No. 180B.—Brook water (Chaffinch Beck) and effluent, taken 55 yards below effluent outfall, a good deal of sewage weed in the stream, volume of effluent to stream approximately as 3 to 1.

Sample No. 182.—Surface water from streets, very full of grit and very turbid. Sample was drawn after the surface drain had been running for three hours; surface water channel contained whitish sewage weed.

Sample No. 187A.—Surface water from streets after a slight rainfall (·04 inch).

Sample No. 188B.—As No. 187A, very turbid, sample taken after drain had been running for four hours (·20 inch rainfall).

EXPERIMENT.

Note.—Two arable fields were employed for this experiment of the areas of 1·25 and 1·0 acres respectively. The land in question had a crop of mangolds during the summer, and had not been sewaged since February, 1900, No artificial manure had been applied; the plots were freshly ploughed about 8 inches deep and ridged two days before commencing the experiment. The sewage was treated twice, being run from the first on to the second plot. The quantity of sewage treated per acre per 24 hours was increased daily from 3,000 gallons the first day, by equal increments of 1,500 gallons, to 39,000 gallons on the 20th December. The second plot of arable received what ever effluent came off the first plot.

Sample No. 181.—The sewage was run on to the first plot at noon, November 26th, 3,750 gallons going on to the 1·25 acres.

This sample was drawn from the effluent which had passed through the surface soil down to the clay subsoil and filtered through cracks in the latter to the pick-up grip at foot of plot. This grip was about 30 yards from the nearest point where the oncoming sewage showed.

There was a very small flow of effluent and not sufficient to reach the second plot, owing to the cracks in the soil. The sewage going on to the land was soapy and fairly strong.

Sample No. 183.—Taken after 4,500 gallons per acre had been going on plot, sewage black and septic looking, partly, no doubt, owing to being backed up in the pipe carrier by the gauging board, some deposit taking place. A mere dribble of effluent going on to the second plot as noon.

Sample No. 185A.—Taken after 6,000 gallons had been going on per acre; sewage about normal; about 2,000 gallons per 24 hours going on to second plot (area 1·0 acre).

Sample No. 185.—This was a sample similar in all respects to No. 181. There was very little effluent coming off.

Samples No. 186A, and No. 186.—After 7,500 gallons going on first plot, 2,800 on the second plot; sewage about normal. Owing to the increased flow the sewage did not appear to be septic, and solids were not held back.

Samples No. 187B, and No. 187C.—After 9,000 gallons first plot, 3,000 gallons second plot. Almost the whole of the first plot had now been sewaged. Previously only about two-thirds of it had been covered owing to small amount of sewage put on. The sewage had not yet reached the top of the plough cuts.

Samples No. 187D and No. 187.—After 12,000 gallons and 5,000 gallons; sewage rather dilute.

Samples No. 188A and No. 188.—After 15,000 and 7,500 gallons; sewage very dilute.

Samples No. 189A and No. 189.—After 18,500 and 11,250 gallons; sewage very dilute, most of it being rain water. Tanks cleaned out the day previous.

Samples No. 189B., and No. 189C.—After 19,500 and 13,125 gallons; sewage stronger than the previous day.

Samples No. 190B. and No. 191.—After 22,500 and 18,800 gallons; sewage normal.

Samples No. 191A. and 192.—After 24,000 and 23,000 gallons; sewage fairly strong.

Samples No. 193 and No. 194.—After 27,000 and 18,000 gallons; sewage much stronger; a great deal of froth on the effluent from the first plot.

Samples No. 194A and No. 194B.—After 28,500 and 23,000 gallons; sewage strong. Almost the entire surface of the second plot had now received sewage.

Samples No. 194C and No. 194D.—After 30,000, and 23,000 gallons; sewage normal.

Samples No. 195A and No. 195.—After 33,000 and 26,250 gallons; sewage about normal; land beginning to smell, sewage weed in pick-up grip at bottom of first plot.

Samples No. 196 and No. 197.—After 36,000 and 33,750 gallons.

Samples No. 197A and No. 198.—After 37,500 and 40,000 gallons; rainfall on first plot caused this excess on the second plot. Sewage very dilute.

Samples No. 199 and No. 200.—Sewage dilute. After increasing the amount on the first plot to a constant flow of about 39,000 gallons per acre per 24 hours, and about 36,000 gallons on the second plot, no more samples were drawn until January 2nd, 1901. The sewage had thus been flowing on to the two plots at the above rate for 12 days, continuously, night and day, and the plots appeared thoroughly overworked, both effluents appearing foul.

* In a few instances samples are referred to in this addendum concerning which no bacteriological records are available. These samples were extra ones, collected by Mr. Kershaw for chemical analysis.

SOUTH NORWOOD SEWAGE FARM.

(Domestic Sewage).

*Comparative Samples.

Effluents treated over one plot.	Effluents treated over two plots.	Effluents treated over three plots.	Remarks.
No.	No.	No.	
—	26	23	*By "comparative" samples is meant samples drawn from the same areas of land, and the effluents in brackets are comparable with each other so far as the area of land sewaged is concerned.
—	171	30	
Arable land.	Arable land.		
No.	No.		
†181	†185	—	†Strictly speaking, the same daily areas of land were not sewaged until late in the experiment.
183	186	—	
185a	187c	—	
186a	187	—	
187b	188	—	
187d	189	—	
188a	189c	—	
189a	191	—	
189b	192	—	
190	194	—	
191a	194b	—	
193	194d	—	
194a	195	—	
194c	197	—	
195a	198	—	
196	200	—	
197a	—	—	
199	—	—	

SECTION VII.

NOTTINGHAM SEWAGE FARM.

1. Situation of farm.—Stoke Bardolph, about 5 miles from Nottingham.

2. Total acreage of farm.—907 acres (1900).

3. Total irrigable area.—651 acres (1900).

4. Average area irrigated at one time.—300 acres.

*5. Population draining to farm.—258,584.

6. Population per acre irrigated.—397.

7. Gallons of sewage per head per day.—27.

8. Dry weather flow of sewage per 24 hours.—7,000,000 gallons.

9. Gallons of sewage (exclusive of storm water) treated per acre per 24 hours.—23,300 = $(\frac{7,000,000}{300})$.

10. Gallons of sewage treated per acre per 24 hours on the assumption that each acre of irrigable area is under sewage all the time. (This for purposes of comparison) $(\frac{7,000,000}{651})$ = 10,750 gallons.

11. Characters of the sewage.—four-sevenths domestic, three-sevenths trade effluent.

12. Method of treatment.—Screening (partial) and land filtration.

13. General characters of the soil and subsoil.—Light sandy loam and gravel overlying gravel and sand.

14. Separate or combined sewerage system.—Combined.

15. The final effluent is discharged into.—River Trent.

16. Number of years farm in operation before 1900.—19½ years.

* It will, however, be seen from Mr. Kershaw's report that a considerable proportion of the æcal matter is kept out of the sewers.

A full description of Nottingham sewage farm will be found in Mr. Kershaw's report. (Part IV., Engineering and Practical Report.) A few of the more important points may here be alluded to, namely, as follows :—

The sewage contains a considerable proportion of trade refuse. The treatment consists of screening (partial) and land filtration. The soil of the farm may be described as a light sandy loam and gravel overlying sand and gravel. It is admirably adapted for sewage purification purposes. Almost no subsoil water reaches the under-drains on the farm. It appears from Mr. Kershaw's report that a good deal of the fæcal matter is kept out of the sewers. The subsoil leakage into the sewers is small. There is no separate system. The storm overflows come into operation when the rainfall exceeds ¼ in. in the 24 hours. The sewage is only passed through the soil once. The entire farm is under-drained. Generally speaking the land is continuously sewaged for 12 hours, "rested" for 12 hours, and then sewaged again. The effluents pass by means of a ditch into the River Trent. The volume of the latter is, under ordinary conditions, 60 to 400 times the combined volume of the effluents. The crops grown on the farm are various, but ryegrass, mangolds, and cabbages are the chief. The gross area of the farm is 907 acres (245 pasture, 615 arable); the irrigable area 651 acres (35 pasture, 615 arable). "*This area of* 651 *acres deals with (excluding storm water) seven million gallons of sewage per* 24 *hours, which is equal to* 10,752 *gallons per acre, or* 397 *persons per acre, approximately. Three hundred acres are irrigated at one time, which corresponds to* 23,300 *gallons treated per acre per* 24 *hours.*"

The following is a summary of the several sections of the Report in so far as it relates to Nottingham :—

1. Tabular statement, and summary of the chief bacteriological results.

2. Diagram 10 illustrating the results shown in Table 16 with comments thereon.

3. Results considered in relation to some of Mr. Kershaw's notes.

4. Results considered in relation to tests other than B. enteritidis sporogenes.

5. Results of the bacteriological examination of additional samples of river water, and mixed river water and effluent.

6. General conclusions.

Addendum A.—Results of the examination by means of simple tests of samples obtained from Nottingham sewage farm (special comparative series of experiments).

Addendum B.—Comparative record as regards (1) the "gas" and (2) B. enteritidis sporogenes tests of samples obtained from Nottingham, as well as other sewage farms.

Addendum C.—Additional bacteriological notes.

Addendum D.—Mr. Kershaw's abridged notes to accompany bacteriological data.

I.—Tabular Statement and Summary of the Chief Bacteriological Results.

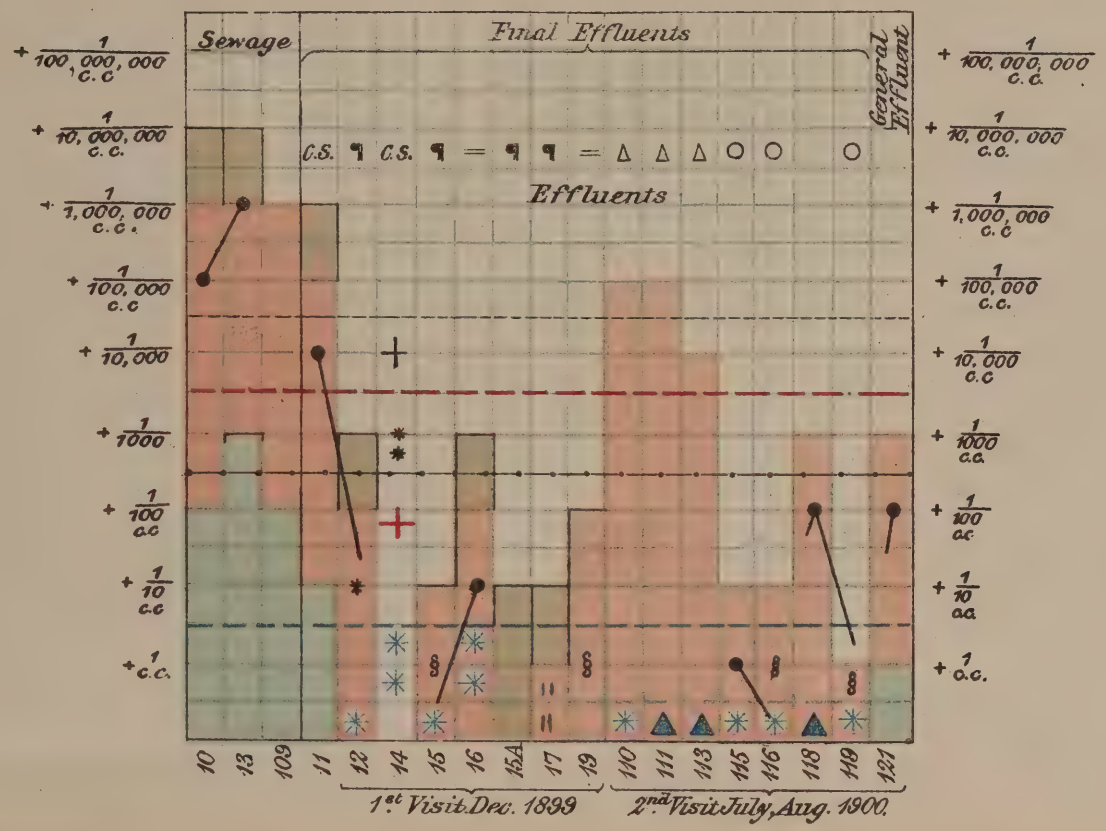
The following table (Table 16) shows as regards the total number of bacteria, B. coli and spores of B. enteritidis sporogenes, the results of the bacteriological examination of various samples obtained from Nottingham sewage farm :—

TABLE 16.—Showing as regards the total number of bacteria, B. coli, and spores of B. enteritidis sporogenes, the results of the bacteriological examination of samples of sewage and of effluents obtained from Nottingham sewage farm.

Description of the Sample.	Total Number of bacteria per c.c.		Number of B. coli (or closely allied forms) per c.c.	Number of Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in milk culture) per c.c.	
	Gelatine at 20° C.	Agar at 37° C.			
1.	2.	3.	4.	5.	
10 Crude Sewage - - - 12 noon, 5th Dec. 1899.	15,100,000	2,510,000	At least 100,000 but less than 1,000,000	+ ·01, – ·001 c.c At least 100 but less than 1,000.	
13 Crude Sewage - - - 12.15 p.m., 12th Dec. 1899.	31,600,000	6,650,000	At least 1,000,000 -	+ ·001, – ·0001 c.c. At least 1,000 but less than 10,000.	
109 Crude Sewage - - - 11.55 a.m., 23rd July 1900.	—	6,280,000	—	+ ·01, – ·001 c.c. At least 100 but less than 1,000.	
Averages - -	23,350,000	5,146,666	[Ratio cols. 2 to 3	=4·5 : 1.]	
11 Final Effluent - - - 1.30 p.m., 5th Dec. 1899.	2,130,000	596,000	At least 10,000 but less than 100,000	+ ·1, – ·01 c.c. At least 10 but less than 100.	First Visit, December 1899.
12 Final Effluent - - - 1.30 p.m., 5th Dec. 1899.	1,000	390	Absent from 0·1 c.c.	None in 10 c.c.	
14 Final Effluent - - - 12 noon, 12th Dec. 1899.	Plates too dilute. (very few)	Plates too dilute. (very few)	Absent from ·001 c.c.	– ·1 c.c. None in $\frac{1}{10}$ c.c.	
15 Final Effluent - - 12.30 p.m., 12th Dec. 1899.	50	11	Absent from 1 c.c.	None in 10 c.c.	
16 Final Effluent - - - 3.15 p.m., 12th Dec. 1899.	1,540	370	At least 10 - -	None in $\frac{1}{10}$ c.c.	
15A Final Effluent - - -	39	—	—	None in 100 c.c.	
17 Final Effluent - - - 19th Dec. 1899.	21	4	Absent from 100 c.c.	Present in 500 c.c.	
19 Final Effluent - - - 20th Dec. 1899.	740	100	Absent from 1 c.c.	—	
110 Final Effluent - - - 2.15 p.m., 23rd July 1900.	—	547,200	—	Negative 10 c.c.	2nd Visit, July and August 1900.
111 Final Effluent - - - 3 p.m., 24th July 1900.	—	210,000	—	+ 10 c.c., – 1 c.c. None in 1 c.c.	
113 Final Effluent - - - 11.4 a.m., 25th July 1900.	—	53,000	—	- ditto.	
115 Final Effluent - - - 2.15 p.m., 30th July 1900.	—	15	1 but less than 10 -	Negative 10 c.c.	
116 Final Effluent - - - 11.45 a.m., 31st July 1900.	—	10	None in 1 c.c. -	- ditto.	
118 Final Effluent - - - 11.30 a.m., 1st August 1900.	—	2,096	At least 100 - -	+ 10 c.c., – 1 c.c. None in 1 c.c.	
119 Final Effluent - - - 11.45 a.m., 1st August 1900.	—	3	None in 1 c.c. -	Negative 10 c.c.	
121 General Effluent - - 6th August 1900.	—	7,000	100 not 1,000 - -	+ 1, – ·1 c.c. At least 1 but less than 10.	
Averages - -	304,770 [98% reduction]	101,157 [98% reduction]	[Ratio cols. 2 to 3	=2·1 : 1.]	

B. enteritidis sporogenes the results of the bacteriological examination of samples of sewage & of effluents obtained from Nottingham sewage farm.

= Total number of bacteria (gelatine at 20° c)	----------	provisional standard	Seven	out	of	Eight	effluents	passed	this standard
= " " " " (agar at 37° c)	— — — —	($-\frac{1}{100,000}$ c.c.)	"	Eleven	"	" Fifteen	"	"	" "
B. Coli	—·—·—·—	($-\frac{1}{10,000}$ c.c.)	"	"	"	" Twelve	"	"	" "
B. enteritidis sporogenes	— — — —	($-\frac{1}{1000}$ c.c.)	"	Fourteen	"	" Fifteen	"	"	" "
		($-\frac{1}{10}$ c.c.)							



C.S. = Comparative samples
¶ = " "
Δ = " "
O = " "
= = " "

* = B. Coli absent ·1 c.c.
** = " " " ·001 c.c.
§ = " " " 1 c.c.
‖ = " " " 100 c.c.

✳ = B. Ent. sporogenes absent 10 c.c.
✳✳ = " " " 0·1 c.c.
§ = " " " 100 c.c.
‖ = " " present 500 c.c.
▲ = " " + 10 c.c.; — 1 c.c.

+ / + Plates too dilute to allow of accurate counting, but certainly easily "passing" the suggested standards.

3311.9.02

Waller & Graham, Ltd Litho London.

Brief summary of the results shown in Table 16 :—

Crude Sewage :—

The crude sewage was in no way exceptional in its biological qualities.* Thus, the total number of bacteria was over ten million (gelatine at 20°C.) and between one and ten million (agar at 37°C.) per c.c. B. coli numbered at least 100,000 and B. enteritidis sporogenes 100 to 1,000 per c.c.

Effluents :—

The effluents were remarkably good; and some of them, apart from a knowledge of their source, might on superficial observation have been classed as drinking waters of great purity.

Total number of bacteria (gelatine at 20°C.) per c.c. :—In three samples, the number was less than 100. In one sample the plate cultures were too dilute to allow of counting being attempted, which would imply a small total number of bacteria. One sample contained more than 100 but less than 1,000. Two samples contained 1,000 and 1,540 respectively per c.c. In one sample only was the number excessive (over two million), and here the land was being greatly overworked.

Total number of bacteria (agar at 37°C.) per c.c. :—In five samples the number was less than 100. Three samples contained respectively 100, 370, and 390 per c.c Two samples contained between 1,000 and 10,000; one sample between 10,000 and 100,000; and three samples more than 100,000 but less than one million. In one sample the plate cultures were too dilute to allow of counting being reliable. which would imply a small total number of bacteria.

B. coli (and closely allied forms) per c.c. :—In one sample B. coli was absent from 100 c.c. Four samples contained none in 1 c.c. In two samples B. coli was absent from 0·1 and ·001 c.c. respectively. In one sample the number was at least 10; in another one, but less than 10; and two samples 100 at least. One sample contained 10,000, but this was from the overworked land.

Spores of B. enteritidis sporogenes per c.c. :—In one sample a negative result was obtained even with the bacterial contents of 100 c.c. In no less than six samples the result was negative with 10 c.c. In three samples a positive result was obtained with 10 c.c., but a negative result with 1 c.c. Three samples contained none in $\frac{1}{10}$ c.c. One sample contained at least 10, but less than 100; this was, however, from the overworked land.

2. *Diagram* 10 *illustrating the results shown in Table* 16, *with comments thereon.*

The results are shown in graphic form in diagram 10.

By referring to the diagram, it will be seen that certain horizontal lines are drawn indicating provisional standards (non-drinking water streams).

All samples which, according to these standards, did not fulfil the following requirements would be tentatively condemned :—

1. Total number of bacteria (gelatine at 20° C.)	Less than 100,000	per c.c.
2. Total number of bacteria (agar at 37° C.)	Less than 10,000	
3. B. coli.	Less than 1,000	
4. B. enteritidis sporogenes.	Less than 10	

As regards (1)	seven out of eight effluents	passed the above standards.
(2)	eleven ,, fifteen ,,	
(3)	eleven ,, twelve ,,	
(4)	fourteen ,, fifteen ,,	

From consideration of the table and diagram, it is obvious that not only did nearly all the effluents pass these standards, but that they passed them quite easily, and further, that some of the effluents, on preliminary observation, seemed, in respect of their biological purity, to challenge comparison with drinking water.

* It will, however, be seen from Mr. Kershaw's notes that a large proportion of the fæcal matter is kept out of the sewers.

Taking the B. enteritidis sporogenes results (*See* Plate IV., Figs. 15 & 16), as a ready means of gauging the degree of biological purification effected in the effluent, it is to be noted that, whereas the sewage contained from 100 to 1000 spores per c.c., the effluents yielded the following results :—

In one sample at least 10, but less than 100 (from overworked land)
" " " 1, " " 10.
" two samples none in 0·1 c.c.
" three " " 1 c.c. (but present in 10 c.c.).
" six " " 10 c.c.
" one " " 100 c.c.

There can be no question, I think, that in the case of Nottingham Sewage Farm a mechanical separation of the microbes was at work. But even so the results under average and seemingly normal conditions of working the land were, not only occasionally, but uniformly good. It would perhaps be unwise to assume the destruction, other than by processes of an extremely gradual character, of the spores of sewage microbes mechanically retained in the soil; but, as regards non-sporing forms of sewage bacteria, more rapid extinction might perhaps tentatively be inferred. The ultimate fate of the sewage bacteria is of considerable interest from the epidemiological point of view, and the merely partial solution of this problem may be the work of many years. The results obtained at Nottingham do not afford sufficient data for advancing other than cautious inferences. But the results so far as they go, judged as a whole, do not seem to indicate that the treatment of land more or less continuously with sewage compasses the destruction of bacilli to a conspicuously greater extent than spores of bacilli. I say to treat more or less continuously, because it is my belief that, if the land were rested for long periods between each application of sewage, such treatment would indeed effect the gradual destruction of non-sporing bacilli while leaving the spores relatively unaffected. This, however, would in practice be impossible, and hence under ordinary conditions of working a farm the application of sewage is too continuous to permit of slow processes of the above sort being readily appreciated, assuming that they are actually in operation.* The subject is further complicated by the circumstance that spores may develop into bacilli and the bacilli multiply and again form spores; further, that the non-sporing microbes may be multiplying in the soil as well as dying.

My work for the Local Government Board on the inoculation of soil with cesspool sewage tends to show that B. coli and streptococci greatly diminish in numbers, if they do not altogether perish in soil, subsequent to a cessation of the inoculation process, the former more slowly than the latter class of microbes. As regards the spores of B. enteritidis sporogenes, the results obtained were sometimes of an anomalous character; but on the whole it may be said that, in comparison with B. coli, the spores persisted in almost undiminished numbers during the progress of the experiments. But, as I have already indicated, where land is heavily and more or less continuously sewaged the conditions are different.

Nevertheless, unless land has an almost infinite power of retaining microbes, and is therefore capable of holding back the majority of the bacteria contained in the sewage which, excepting the period of complete rest occasionally given, is sometimes almost continuously, at other times intermittently, poured on it year after year, we must conclude that the relatively small number of bacteria observed in the effluents means that there exists a continual process of destruction as well as of a mere mechanical separation of the sewage microbes. It may be noted in this connection that the Nottingham Sewage Farm has been in operation over 20 years.

* Both as regards land and bacteria bed processes for sewage treatment, it is surprising to find that usually the effluents show a percentage reduction in the number of spores of bacteria not widely different from the percentage reduction in the number of bacilli. Sometimes, it is true, there is evidence of a greater proportionate reduction of the non-sporing microbes, but seldom, if ever, to the extent that might, perhaps, be anticipated. For example, it is remarkable that effluent 15A which contained 39 microbes per c.c. yielded a negative result as regards the spores of B. enteritidis sporogenes, even when the bacterial contents of 100 c.c. were submitted to cultivation.

3. *Results considered in relation to Mr. Kershaw's notes.**

In a number of respects, Mr. Kershaw's notes merit attention. For example, as regards the comparative samples 11 and 14, he says :—

Sample No. 11.—The plot from which this effluent was drawn was purposely sewaged very heavily night and day in order to obtain a bad effluent ; and after a sample had been drawn of this effluent, the plot was sewaged 12 hours by night only for seven days, when Sample No. 14 was drawn of the effluent ; the object in view being to ascertain how long the land took to recover its purifying properties.

The bacteriological results considered in relation to the above statement are of interest. Thus sample 11 gave the following results :—

> Over 2 million bacteria (gelatine at 20° C.) ; more than 100,000 microbes (agar at 37° C.) ; at least 10,000 B. coli ; and at least 10 spores of B. enteritidis sporogenes per c.c. The effluent was thus very unsatisfactory, and failed to pass any of the standards relating to the above tests.

Sample 14, on the other hand, was a very satisfactory effluent, as the following notes clearly show :—

The total number of bacteria was not estimated, as the plates were found to be too dilute for accurate counting, but this implies that the effluent was well within the limits of the suggested standard. Similarly, the excellent qualities of the effluent were under-estimated in making cultures for B. coli and B. enteritidis sporogenes ; and the negative result with ·001 c.c. and ·1 c.c., respectively, in connection with these two tests probably considerably under-estimates the purity of the sample.

It is of interest to notice that samples 15 and 15A, although collected from a field superficially frozen over, yielded, nevertheless, remarkably good results. In sample 15, B. coli was absent from 1 c.c., and the spores of B. enteritidis sporogenes from 10 c.c. In sample 15A, no spores of B. enteritidis could be found even in the bacterial contents of 100 c.c., which is a remarkably good result.

As regards samples 16 and 19, it appears from Mr. Kershaw's notes that between the times of collection of the two samples of effluent a rest of three days intervened. The beneficial effect of the rest is shown by the biological results.

Sample 17 was comparative with samples 12, 15 and 15A, and it is worthy of note that this sample actually contained no B. coli in 100 c.c. (Bacterial contents of 100 c.c. obtained by Pasteur filter brushing method). The comparative samples 110, 111 and 113 were much less satisfactory as regards total number of bacteria (agar at 37° C.), although they passed easily the B. enteritidis sporogenes standard. These samples were derived from a 12-acre plot of land (mangolds), and represented the result of sewaging the land one, two, and three days respectively with day sewage for 12 hours, and it may be that the land had not got properly into working order. Possibly sewage microbes stored in the soil were being washed out of the soil.

Comparative samples 115, 116 and 119 from an 11-acre plot of land (cabbage) sewaged 14, 15 and 16 days respectively with day sewage for 12 hours, all yielded very good results on bacterioscopic analysis.

Samples 118 and 121, the former a final effluent and the latter a general effluent, although not so pure biologically as the foregoing, satisfactorily passed the different standards suggested.

4. *Results in relation to tests other than the B. enteritidis sporogenes test.*

So far the records as regards the B. enteritidis sporogenes test have been chiefly, although not exclusively, considered, and it is necessary to make some further observations on the bacteriological results shown in table 16 and diagram 10.

As regards the total number of bacteria (gelatine at 20° C. and agar at 37°C) the averages work out as follows :—

	Gelatine at 20°C., Microbes per c.c.	Agar at 37°C., Microbes per c.c.	Ratio.
Sewage - - - -	23,350,000	5,146,666	4·5 : 1
Effluents - - -	304,770 [98% reduction.]	101,157 [98% reduction.]	2·1 : 1

* Addendum D, page 137.

These figures are, I think, somewhat misleading, and must not, therefore, too readily be considered as an entirely reliable indication of the average quality of the effluents from the farm during the period of survey. In point of fact, a few relatively bad effluents have, so far as averages are concerned, spoiled the excellent quality of the majority of the effluents. Since this is the case, it must also be added that a general survey of all the results leads me to the conclusion that, despite the extraordinary purification effected by the land treatment at Nottingham, the intrinsic biological qualities of the original sewage were not destroyed, but only "masked" to a remarkable extent. A single example will suffice to illustrate my meaning. In sample 115 there were present only 15 microbes (agar at 37° C.) per c.c., yet B. coli was present in the proportion of at least one to the c.c.

From the epidemiological point of view, the effluents from Nottingham Sewage Farm would thus be classed by the bacteriologist as relatively not absolutely safe. It is to be regretted that more samples were not obtained from Nottingham, although this deficiency is to a considerable extent supplemented by the subsequent examination of fifteen samples by simple tests (Addendum A.). In Addendum C. will also be found the results, as regards total number of bacteria, number of B. coli and indol-producing bacteria, of the bacteriological examination of a few additional samples. These samples, although yielding excellent results, clearly showed their relationship to matters of excremental origin.

In the table and diagram illustrating Appendix III. (page 196), the results as regards the "gas" and B. enteritidis sporogenes tests are brought into comparison. Of eight effluents, seven passed both these tests and the one that failed (11) came from land which had been purposely over-sewaged for some time.

Indol test (indol in broth cultures, five days at 37° C.) :—

Sample	119	gave a	negative	result	with	1 c.c.
,,	116	,,	positive	,,	,,	1 c.c.
,,	115	,,	,,	,,	,,	0·1 c.c.
,,	118	,,	,,	,,	,,	0·01 c.c.
,,	121	,,	,,	,,	,,	0·001 c.c.

5. *Results of the bacteriological examination of additional samples of river water and river water mixed with effluent.*

The results of the examination of these samples is shown in Table 17.

TABLE 17.—Showing the results of the bacteriological examination of samples of: (1) Trent river water above the effluent outfall; (2) effluent obtained from Nottingham Sewage Farm; and (3) mixed effluent and river water.

Description of the Sam le.	Total number of bacteria per c.c. —— Agar at 37° C.	Number of B. coli (or closely allied forms) per c.c.	Number of spores of B. enteritidis sporogenes (Klein's "enteritidis change" in milk culture) per c.c.
120 Trent river water above effluent outfall. Aug. 6th 1900.	3,300	100 not 1,000 [Indol + ·001 c.c.]	+ 1 – ·1 c.c. At least 1 but less than 10.
121 Effluent (final) - - - - Aug. 6th 1900.	7,000	100 not 1,000 [Indol + ·001 c.c.]	+ 1 – ·1 c.c. At least 1 but less than 10.
122 Effluent + river water. Aug. 6th 1900. (50 yards below 121).*	12,224	1,000 not 10,000 [Indol + ·0001 c.c.]	+ 1 – ·1 c.c. At least 1 but less than 10.
123 Same, lower down. Aug. 6th 1900. (120 yards below 121).	6,336	100 not 1,000 [Indol + ·001 c.c.]	+ 1 – ·1 c.c. At least 1 but less than 10.

As regards the total number of bacteria (agar at 37° C.), it is to be noted that the river water (120) above the effluent outfalls contained more than half the number of microbes in the effluent itself (121). The mixed river water and effluent (122) contained more microbes than the effluent alone (121). Lower down (123), however, the number fell to about that found in the effluent (121).

* Ratio of effluent to river water about 1 : 160.

Samples 120, 121 and 123 all yielded the same results as regards B. coli, namely, 100 not 1,000 per c.c. Sample 122 contained 1,000 in 1 c.c.

All the samples gave, as regards B. enteritidis sporogenes test, the same results, namely, at least 1 but less than 10 spores per c.c.

These isolated observations are of more importance from the chemical than the bacteriological point of view, and it would, perhaps, be unwise to attempt to draw any conclusions from them. But, if the results obtained from the examination of the various samples represent the normal conditions, it would seem as though the bacteria in the effluent underwent some preliminary multiplication in the river.

6. *General Conclusions.**

The results as a whole were unquestionably very good, and some of the effluents might on superficial observation and without a knowledge of their source have been classed as pure drinking water.† But, as has already been pointed out, evidence was not lacking that the intrinsic biological qualities of the sewage were not materially altered by the land treatment but only "masked" to a remarkable extent. If this supposition be correct, and the additional records given in Addenda A and C confirm this view, immunity from danger to health arising from the discharge of such effluents into drinking water streams would be relative not absolute. But, whether or no question arises as to the propriety of discharging effluents possessed of the biological qualities observed in the case of the Nottingham effluents into a drinking water stream, there can be no doubt as to the fitness of these effluents to discharge into a river not used for potable purposes. None of the other sewage farms under investigation yielded effluents which approached the degree of biological purification effected by the land treatment in the case of Nottingham Sewage Farm.

Addendum A.—*Results of the examination by means of simple tests of samples obtained from Nottingham Sewage Farm. (Special Comparative Series of Experiments.)*

Four samples of sewage and 15 samples of effluent were examined by (1) the "gas" test, (2) B. enteritidis sporogenes test and (3) neutral-red broth test.

The results, which were strikingly good, are shown in Table 18 and Diagram‡ 11. Thus as regards (1) three of the samples of the sewage gave a positive result with ·0001 c.c., and one with ·001 c.c. All the 15 samples of effluent passed the standard suggested (negative result 0·1 c.c.), three of these gave a positive result with 1 c.c. but not with 0·1 c.c.; while the remaining twelve gave a negative result with 1 c.c.

As regards (2) three of the samples of sewage gave a positive result with ·001 c.c. and one with ·01 c.c. All but one of the 15 samples of effluent passed the standard suggested (negative result 0·1 c.c.), and this one was within measurable distance of passing. Of the satisfactory 14, one gave a positive result with 1 c.c. but a negative with 0·1 c.c., while the remaining 13 gave a negative result with 1 c.c.

As regards (3) all four samples of sewage gave a positive result with ·00001 c.c. All but one of the effluents passed the standard suggested (negative result ·001 c.c.), and this one was very nearly satisfactory. Of the remaining 14, four gave a positive result with ·01 but not with ·001 c.c., nine gave a positive result with ·1 but a negative with ·01 c.c., and one gave a negative result with ·1 c.c.

From Mr. Kershaw's notes, it appears that samples 330, 335, 338, 343, 347 are comparative, that is, drawn from the same area of land. Similarly, 331, 336, 339, 344, and 348 are comparable. Further that samples 330, 331, 335, 336, 338, 339, 343, 344, 347, 348 were final effluents, and samples 332, 333, 340, 341, 346 general effluents.

* The general conclusions are based on the results given in the Addenda as well as on those previously considered. For statistical information, see tabular statement at the beginning of this report, Section VII.

† For example, final effluents 15, 17, 115, 116 and 119 contained 11, 4, 15, 10 and 3 microbes (agar at 37° C.) respectively per c.c.

‡ See also the diagram illustrating Appendix II, in which the Nottingham, Aldershot, Beddington, and Leicester results are brought into comparison with each other (page 194).

TABLE 18.—Showing as regards the (a) "Gas," (b) B. enteritidis sporogenes, and (c) Neutral red-broth tests, the results of the bacteriological examination of four samples of crude sewage and fifteen samples of effluent obtained from Nottingham Sewage Farm.

(The double line in each case refers to a provisional standard (non-drinking water streams). The sign + occurring on the right hand side of this line means that the effluent is condemned on the basis of this standard.)

Description of Sample.	"Gas" in gelatine "shake" culture (24 hours at 20 °C.)						Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures).						Neutral red-broth test (24 hours at 37° C. Greenish yellow fluorescence = positive result. No change in colour = negative result.						Sewage Farm.
	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	.00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c c.	·01 c.c.	·001 c.c.	·0001 c.c.	00001 c.c.	
329. *Crude Sewage* - - - - - - - - - - - (1.50 p.m., 23rd September 1901, air 68° F., sample 67° F.)					+					+	–							+	Nottingham.
330. Final effluent - - - - - - - - - - - - (2.20 p.m. 23rd September 1901, air 68° F., sample 56° F.)	–						–							+	–				
331. Final effluent - - - - - - - - - - - - (2.30 p.m., 23rd September 1901, air 67° F., sample 56° F.)	+	–					+	–							+	–			
332. General effluent - - - - - - - - - - - (2.45 p.m., 23rd September 1901, air 67° F., sample 56° F.)	+	–						+	–						+	–			
333. General effluent - - - - - - - - - - - (11.30 a.m., 24th September 1901, air 60° F., sample 56° F.)	–						–								+	–			
334. *Crude Sewage* - - - - - - - - - - - (11.35 a.m., 24th September 1901, air 60° F., sample 67° F.)					+	–			+	–								+	
335. Final effluent - - - - - - - - - - - (11.45 a.m., 24th September 1901, air 60° F., sample 56° F.)	–						–							+	–				
336. Final effluent - - - - - - - - - - - (11.50 a.m., 24th September 1901, air 60° F., sample 56° F.)	–						–									+	–		
337. *Crude Sewage* - - - - - - - - - - - (11.45 a.m., 25th September 1901, air 68° F., sample 68° F.)				+	–					+	–							+	
338. Final effluent - - - - - - - - - - - (12.30 p.m., 25th September 1901, air 70° F., sample 56° F.)	–						–							+	–				
339. Final effluent - - - - - - - - - - - (12.35 p.m., 25th September 1901, air 70° F., sample 55° F.)	–						–							+	–				
340. General effluent - - - - - - - - - - - (4.15 p.m., 25th September 1901, air 62° F., sample 55° F.)	–						–							+	–				
341. General effluent - - - - - - - - - - - (11.30 a.m., 26th September 1901, air 66° F., sample 56° F.)	–						–								+	–			
342. *Crude Sewage* - - - - - - - - - - - (11.35 a.m., 26th September 1901, air 66° F., sample 68° F.)					+	–				+	–							+	
343. Final effluent - - - - - - - - - - - (11.45 a.m., 26th September 1901, air 66° F., sample 56° F.)	–						–							+	–				
344. Final effluent - - - - - - - - - - - (11.45 a.m., 26th September 1901, air 66° F., sample 56° F.)	–						–							+	–				
346. General effluent - - - - - - - - - - - (11.30 a.m., 27th September 1901, air 62° F., sample 56° F.)	+	–					–							+	–				
347 Final effluent - - - - - - - - - - - (11.45 a.m., 27th September 1901, air 62° F., sample 56° F.)	–						–							+	–				
348. Final effluent - - - - - - - - - - - (11.50 a.m. 27th September 1901, air 62° F., sample 55° F.)	–						–							–					

Diagram 11 showing, as regards the (a) "gas"; (b) B. enteritidis sporogenes; & (c) neutral red broth tests, the results of the bacteriological examination of four samples of crude sewage & fifteen samples of effluent obtained from Nottingham sewage farm.

The horizontal black line in each case refers to a provisional standard.

Weller & Graham, Ltd Litho. London.

Addendum B.—*Comparative records as regards (a) the "gas" test and (2) B. enteritidis sporogenes test of samples obtained from Nottingham as well as other sewage farms.*

These results are shown in the tables and diagram illustrating Appendix III. (page 196) and they include all the samples (from other sewage farms as well as Nottingham) which were examined by both of these tests. These records are additional to the special series of comparative samples already described in Addendum A; the records include altogether 194 samples, of which ten are from Nottingham Sewage Farm. The Nottingham results have been already alluded to in a previous section, and here it is only necessary to repeat that of eight effluents seven passed the standard set up for both these tests. The exception was an effluent from land which had been purposely over-dosed with sewage, in order to ascertain whether a subsequent rest would enable the land to regain its power of purifying sewage. This point was satisfactorily established, as has been previously explained.

Addendum C.—*Additional bacteriological notes.*

The following bacteriological notes are additional to the records previously considered.

Inoculation experiments.

Effluent 12. 3 c.c. of this effluent were injected subcutaneously into a guinea-pig. The animal died on the 24th day from pseudo-tuberculosis. (B. pseudo-tuberculosis of A. Pfeiffer).

Effluent 111. 4 c.c. of this effluent were injected subcutaneously into a guinea-pig. There was little or no local reaction and the rodent remained alive and well.

Effluent 113. 8 c.c. of this effluent were injected subcutaneously into a guinea-pig. A big localised swelling developed, but the animal eventually recovered completely from the effects of the inoculation.

Four guinea-pigs (a) (b) (c) (d) were inoculated each with 20 c.c. of a sample of crude sewage after preliminary treatment as follows :—

(1)	Heated to 65°C. for 20 minutes	In each case rendered germ free by filtration through a sterilised Pasteur's filter, and the filtrate use for inoculation purposes.
(2)	,, 80°C. ,, 10 minutes	
(3)	,, 100°C. ,, 60 minutes	
(4)	,, Not subjected to any preliminary treatment	

The animals remained lively and well and were seemingly but little, if at all, affected by the injections.

Description of the chief morphological and biological characters of a vibrio isolated from ·0001 *c.c. of crude sewage No.* 10.

Source :—Agar plate culture ·0001 c.c. crude sewage No. 10.

Temperature.—Grows well both at 37° C. and at the room temperature.

Morphological characters.—A vibrio resembling morphologically somewhat closely Koch's vibrio. Does not stain very readily with the ordinary aniline dyes. (*See* Plate IV. Figs. 13 and 14).

Motility.—Very actively motile.

Agar streak cultures (37° C.).—White thin film-like growth having no very special characters.

Gelatine streak cultures (20° C.).—Thin transparent meagre growth. No liquefaction occurs.

Gelatine stab cultures (20° C.).—Meagre growth down line of stab, on the surface thin transparent film like expansion. No liquefaction.

Broth cultures (20° C.).—Diffuse but not very abundant cloudiness.

Cholera red reaction.—Negative result even after 10 days' incubation at 37° C. in peptone broth.

Litmus milk cultures (37° C.).—Little or no visible change occurred after incubation. Possibly, however, a trace of alkali was produced.

Remarks.—Probably allied to the non-chromogenic vibrios described by Weibel.

Streptococci.—No streptococci could be found in relatively large amounts of effluents 12, 14, 15, 16, and 16A.

But an agar plate culture (37°C) made from ·001 c.c. of effluent 11, yielded a microbe (microbe A) which resembled in some respects a streptococcus, in others a staphylococcus.

As regards the crude sewage, streptococcus (1) was isolated from ·0001 c.c. of effluent 10 and streptococcus (3) from ·001 c.c. of effluent 13.

The following is a description of some of the chief morphological and biological character of these streptococci :—

Description of Streptococcus.	Streptococcus (1).	Microbe A.	Streptocuccus (3).
Source - - - -	Surface agar plate culture (37°C.) ·0001 c.c.	Surface agar plate culture (37°C.), ·001 c.c.	Surface agar plate culture (37°C.) ·001 c.c.
Morphology - - -	Chains of cocci of medium length many involution forms	Cocci resembling in some respects streptococci, in others staphylococci; stain well by Gram's method	Cocci in chains of considerable length, many involution forms; stains well by Gram's method.
Agar plate cultures (37°C.) under a low power)	Minute transparent colonies, roughly circular in shape with wavy granulation. Loops of cocci may be seen at the periphery	The growth rather too opaque and luxuriant in character to be quite like a streptococcus	Minute, transparent, nearly circular colonies. No separate loops of cocci could be made out at the edge.
Gelatine plate cultures (20°C.) (under a low power)	Small circular transparent looking colonies showing only very faint granulation. Loops of cocci not visible at the periphery	Here the growth was very like a streptococcus, the colonies being minute and transparent looking and growing very slowly	
Gelatine streak cultures (20°C.)	Minute transparent-looking colonies	Growth scanty, minute transparent - looking colonies, eventually softening of gelatine	Minute transparent-looking colonies.
Broth cultures (37°C) -	Slight diffuse cloudiness, at foot and sides of tube white, stringy, viscous growth	Dense uniform turbidity	Diffuse cloudiness and some granular cloudiness as well.
Litmus milk cultures (37°C.)	Strong acid but no clot -	Strong acid but no clot	Acidity but no clot.
Remarks - - -	Not pathogenic to mice -	Not pathogenic to mice	Not pathogenic to mice.

Spores of aerobic bacteria.—The number of spores of aerobic bacteria was determined in samples 10 (crude sewage), 11 (effluent), and 12 (effluent), and found to be 330, 125, and 4, respectively per c.c. In none of the cultures were any colonies of B. mycoides noted. This is a point of some importance since the spores of B. mycoides are present in great abundance in most cultivated soils.* The absence of B. mycoides in the present case tends (so far as isolated observations can be relied on), to show that the passage of the effluents through the soil did not result in the effluents carrying away with them soil microbes to any appreciable extent. That is, the vast majority of the bacteria found in the effluents were not derived from the soil, but from the sewage. In connection with all the sewage farms that were made the subject of bacteriological investigation, the comparative absence both as regards bacilli and spores of bacilli of "soil microbes" from the effluents was constantly noted.

* Reports on the bacteriological examination of soils and soil "washings," Local Government Board.

During September 1901, a few additional samples were examined. The results obtained, which are not included in the general table, are given below :—

Description of sample.	Total number of bacteria per c.c.		Number of B. coli per c.c.	Indol test (indol in broth cultures. 5 days at 37° C.)
	Gelatine at 20° C.	Agar at 37° C.		
329. 23rd Sept. 1901. Crude sewage.	52,000,000	4,040,000	100,000	+ ·00001 c.c.
332. 23rd Sept. 1901. General effluent.	34,000	4,700	Less than 1,000	+ ·001 ; – ·0001 c.c.
333. 24th Sept. 1901. General effluent.	34,000	1,110	100 not 1,000	+ ·01 ; – ·001 c.c.
335. 24th Sept. 1901. Final effluent.	9,100	580	10 not 100	+ ·01 ; – ·001 c.c.
	(All these effluents easily passed the standard of less than 100,000 microbes per c.c.)	(All these effluents easily passed the standard of less than 10,000 microbes per c.c.)	(All these effluents passed the standard of less than 1,000 B. coli per c.c.)	(333 and 335, but not 332, passed the standard of a negative result with ·001 c.c.)

Plate IV.

Figure 13.—Microscopic preparation from an agar culture (24 hours at 37 C.) of vibrio (1), isolated from 0·0001 c.c. of Nottingham crude sewage No. 10.

[Magnifying power, 500.]

Figure 14.—The same more highly magnified.

[Magnifying power, 1,000.]

Figure 15.—B. enteritidis sporogenes test. From left to right the tubes represent 1 c.c. of Nottingham land effluent No. 331 (positive result); 0.1 c.c. of the same sample (negative result); and 1 c.c. of Nottingham land effluent No. 330 (negative result). The standard suggested in connection with this test is a negative result with 0·1 c.c., so both these samples (330 and 331) of effluent "passed" the standard. Effluent No. 330 was particularly satisfactory in relation to this test, since it gave a negative result even with 1 c.c. of the sample.

[About natural size.]

Figure 16.—B. enteritidis sporogenes test. From left to right the tubes represent 1 c.c.; 0·1 c.c.; and 0.01 c.c. of Nottingham land effluent No. 332. It will be noted that the first two tubes show a positive result and the third one a negative result. This effluent, therefore, just failed to pass the standard suggested, namely, a negative result with 0·1 c.c.

[About natural size.]

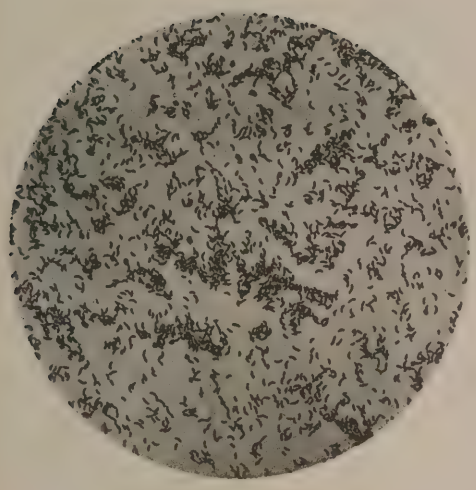


Fig. 13.

Fig. 14.

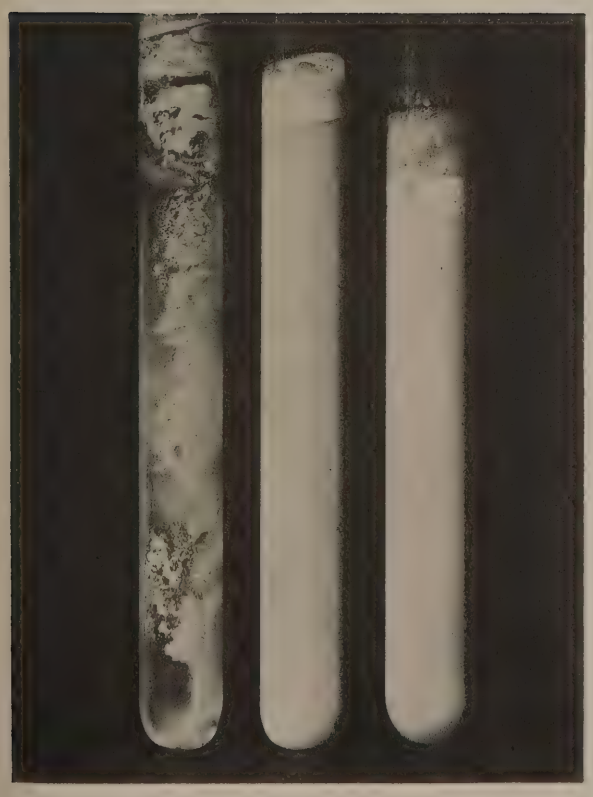


Fig. 15.

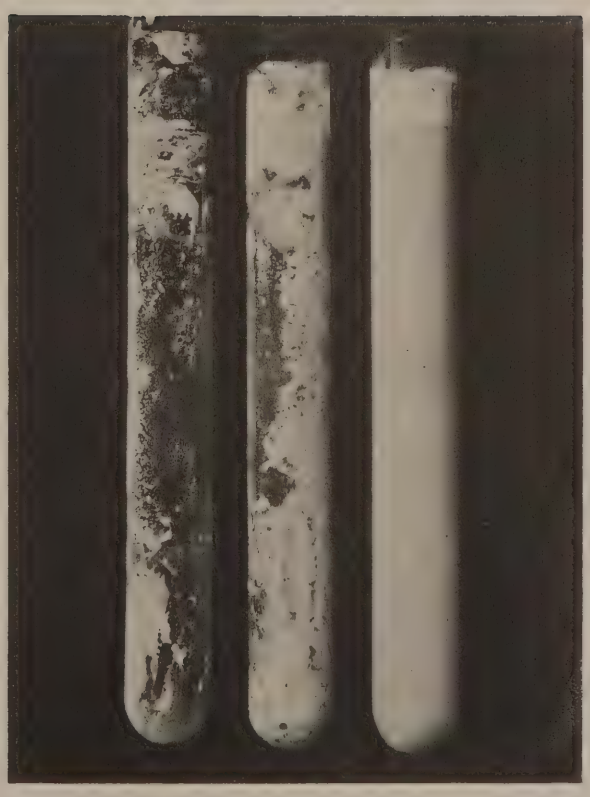


Fig. 16.

ADDENDUM D.—*Mr. Kershaw's abridged notes to accompany bacteriological data.**

NOTTINGHAM SEWAGE FARM.

Additional Notes on Samples.

Sample No. 11.—The plot from which this effluent was drawn was purposely sewaged very heavily night and day in order to obtain a bad effluent; and after a sample had been drawn of this effluent, the plot was sewaged 12 hours by night, only for 7 days, when sample No. 14 was drawn; the object in view being to ascertain how long the land took to recover its purifying properties.

Sample No. 15.—The field from which this sample was drawn was under ice at the time, the sewage continuing to flow underneath.

Samples Nos. 16 and 19.—These samples were from a plot which had been sewaged with day sewage on for 12 hours each day. The plot referred to was rested for 3 days between the two samples Nos. 16 and 19.

Sample No. 112.—River Trent water taken above sewage farm. River rather low for the time of year, a fairly clear sample. The river appeared to be in good condition.

Sample No. 117.—River Trent water taken above farm. River rather high, water rather discoloured, owing to flood water.

Sample No. 120.—River Trent water taken above effluent outfalls; river high and water discoloured.

Sample No. 122.—River Trent water and effluent (ratio of effluent to river water about 1:160) on mixing 50 yards below 121.

Sample No. 123.—As above, but taken further down the river, 120 yards below 121.

Sample No. 330.—A very clear effluent.

Sample No. 331.—As above.

Sample No. 332.—General effluent some decayed leaves, etc., from neighbouring hedges had blown into the main effluent culvert, from which the sample was drawn.

Sample No. 333.—As above. A drinking place for cattle in the effluent culvert had been used earlier in the day.

Samples Nos. 340, 341, 346.—General effluents. All containing bits of decayed leaves previously alluded to. All the final effluents were perfectly clear, colourless and odourless.

* In a few instances samples are referred to in this addendum concerning which no bacteriological records are available. These were extra samples collected by Mr. Kershaw for chemical analysis.

NOTTINGHAM SEWAGE FARM.

Domestic Sewage and Bleach, Dye, Brewery, Laundry, Fellmongers, Woolscouring, and Bone Works Refuse.

Number of Sample.	Date of drawing Sample.	Time of day.	Rainfall day previous to drawing Sample.	Rainfall day of drawing Sample.	Air temperature time of drawing Sample.	Temperature of Sample.	Maximum temperature during the 24 hours.	Minimum temperature during the 24 hours.	Humidity (9 a.m.)	Dissolved oxygen in Sample.	Brief description of Sample.	Remarks.
	1899:		Inches	Inches.	°C. °F.	°C. °F.	°C. °F.	°C. °F.				
10	5 December -	12 (noon)	·15	·24	9·4 (59)	15·0 (59)	9·4 (49)	8·3 (47)	—	—	Screened and crude sewage.	Heavy rainfall during the night.
11	5 ,, -	1.30 p.m.	·15	24	—	8·8 (48)	9·4 (49)	8·3 (47)	—	—	Final effluent - - -	Mean maximum temperature, 3·8° C. (39° F.)
12	5 ,, -	1.35 p.m.	·15	24	—	11·1 (52)	9·4 (49)	8·3 (47)	—	—	,, ,, - - -	Mean minimum temperature, – 1·1° C. (29·9° F.)
13	12 ,, -	12.15 p.m.	·05 snow	·04 snow	—	15·0 (59)	- 1·1 (30)	0·5 (33)	—	—	Screened and crude sewage.	Mean daily rainfall 0·036 in. For the period December 3rd to December 22nd, 1901.
14	12 ,, -	12 (noon)	·05 snow	·04 snow	—	9·4 (49)	- 1·1 (30)	0·5 (33)	—	—	Final effluent - - -	
15	12 ,, -	12.30 p.m.	·05 snow	·04 snow	—	9·4 (49)	- 1·1 (30)	0·5 (33)	—	—	,, ,, - - -	
16	12 ,, -	3 p.m.	·05 snow	·04 snow	17·2 (63)	10·0 (50)	- 1·1 (30)	0·5 (33)	—	—	,, ,, - - -	*Note.*—Samples which may have been affected by rainfall or snow are underlined.
17	19 ,, -	—	·04	·00	—	10·0 (50)	2·2 (36)	1·1 (34)	—	—	,, ,, - - -	
18	20 ,, -	4 p.m.	·00	·00	—	10·0 (50)	2·2 (36)	1·1 (34)	—	—	,, ,, - - -	
19	20 ,, -	4 p.m.	·00	·00	—	10·0 (50)	2·2 (36)	1·1 (34)	—	—	,, ,, - - -	*Carrier overflowed during the night and the area thus received more than its proper amount of sewage.
20	21 ,, -	3.45 p.m.	·00	·00	—	8·8 (48)	2·7 (37)	1·1 (34)	—	—	*,, ,, - - -	
	1900:											
109	23 July -	11.55 a.m.	·00	·00	25·0 (77)	20·0 (68)	29·4 (85)	17·2 (63)	—	—	Screened and crude sewage.	
110	23 ,, -	2.15 p.m.	·00	·00	24·4 (76)	11·6 (53)	29·4 (85)	17·2 (63)	—	—	Final effluent - - -	
111	24 ,, -	3 p.m.	·00	00	27·7 (82)	11·6 (53)	30·0 (86)	17·7 (64)	—	—	,, ,, -	Mean maximum temperature, 23·1° C., (73·7° F.)
112	24 ,, -	4 p.m.	·00	·00	27·7 (82)	22·2 (72)	30·0 (86)	17·7 (64)	—	—	River Trent water - -	Mean minimum temperature, 12·3° C., (54·2° F.)
113	25 ,, -	11.45 a.m.	·00	·00	27·7 (82)	11·6 (53)	30·5 (87)	14·4 (58)	—	—	Final effluent - - -	Mean daily rainfall, 0·19 in. For the period July 22nd to August 8th, 1900.
114	30 ,, -	12.15 p.m.	·22	·00	19·4 (67)	16·6 (62)	22·2 (72)	10·0 (50)	—	—	Screened and crude sewage.	
115	30 ,, -	2.15 p.m.	·22	·00	20·0 (68)	10·5 (51)	22·2 (72)	10·0 (50)	—	—	Final effluent - - -	
116	31 ,, -	11.45 a.m.	·00	·38	20.0 (68)	10·5 (51)	23·3 (74)	14·4 (58)	—	—	,, ,, - - -	
117	31 July -	12.30 p.m.	·00	·38	21·6 (71)	18·8 (66)	23·3 (74)	14·4 (58)	—	—	River Trent water above farm.	
118	1 August -	11.30 a.m.	·38	·05	20·0 (68)	12·7 (55)	21·1 (70)	12·2 (54)	—	—	Final effluent - - -	

119	1 August -	11.45 a.m.	·38	·05	20·0 (68)	10·5 (51)	21·1 (70)	12·2 (54)	—	—	Final effluent - - -	
120	6 „ -	11.30 a.m.	·30	1·25	14·4 (58)	14·4 (58)	18·3 (65)	10·5 (51)	—	—	River water above effluent outfall.	
121	6 „	11.45 a.m.	·30	1·25	15·0 (59)	12·7 (55)	18·3 (65)	10·5 (51)	—	—	§ General effluent - -	§ By "General" effluent is meant a mixture of two or more finally-treated effluents on leaving the farm.
122	6 „ -	12 (noon)	·30	1·25	13·8 (57)	14·4 (58)	18·3 (65)	10·5 (51)	—	—	River water and general effluent	
123	6 „ -	12.30 p.m.	·30	1·25	13·3 (56)	14·4 (58)	18·3 (65)	10·5 (51)	—	—	„ „ „	
	1901:											
329	23 September -	1.50 p.m.	·01	00	20·0 (68)	19·4 (67)	19·4 (67)	12·2 (54)	—	—	Screened and crude sewage.	
330	23 „ -	2.20 p.m.	·01	·00	20·0 (68)	13·3 (56)	19·4 (67)	12·2 (54)	—	—	Final effluent - - -	
331	23 „ -	2 30 p.m.	·01	·00	19·4 (67)	13·3 (56)	19·4 (67)	12·2 (54)	—	—	„ „ - - -	
332	23 „ -	2.45 p.m.	·01	·00	19·4 (67)	13·3 (56)	19·4 (67)	12·2 (54)	—	—	General effluent - -	Mean maximum temperature, 20·1°C (68·25° F.)
333	24 „ -	11 30 a.m.	·00	·00	15·5 (60)	13·3 (56)	19·4 (67)	11·1 (52)	—	—	„ „ - -	Mean minimum temperature, 10° C (50° F.)
334	24 „ -	11.35 a.m.	·00	·00	15·5 (60)	19·4 (67)	19·4 (67)	11·1 (52)	—	—	Screened and crude sewage	Mean daily rainfall, ·00 inches.
335	24 „ -	11.45 a.m.	·00	·00	15·5 (60)	13·3 (56)	19·4 (67)	11·1 (52)	—	—	Final effluent - - -	For the period, September 23rd to September 26th, 1901.
336	24 „ -	11.50 a.m.	·00	·00	15·5 (60)	13·3 (56)	19·4 (67)	11·1 (52)	—	—	„ „ - - -	
337	25 „ -	11.45 a.m.	·00	·00	20·0 (68)	20·0 (68)	20·5 (69)	8·3 (47)	—	—	Screened and crude sewage.	
338	25 „ -	12.30 p.m.	·00	·00	21·1 (70)	13·3 (56)	20·5 (69)	8·3 (47)	—	—	Final effluent - - -	
339	25 „ -	12 35 p.m.	·00	·00	21·1 (70)	12·7 (55)	20·5 (69)	8·3 (47)	—	—	„ „ - - -	
340	25 „ -	4.15 p.m.	·00	·00	16·6 (62)	12·7 (55)	20·5 (69)	8·3 (47)	—	—	General effluent - -	
341	26 „ -	11 30 a.m.	·00	·00	18·8 (66)	13·3 (56)	21·1 (70)	8·3 (47)	—	—	„ „ - -	
342	26 „ -	11.35 a.m.	·00	·00	18·8 (66)	20·0 (58)	21·1 (70)	8·3 (47)	—	—	Screened and crude sewage.	
343	26 „ -	11.45 a.m.	·00	·00	18·8 (66)	13·3 (56)	21·1 (70)	8·3 (47)	—	—	Final effluent - - -	
344	26 „ -	11.50 a.m.	·00	·00	18·8 (66)	12·7 (55)	21·1 (70)	8·3 (47)	—	—	„ „ - - -	
345	26 „ -	3 p.m.	·00	·00	21·1 (70)	20·5 (69)	21·1 (70)	8·3 (47)	—	—	Screened and crude sewage.	
346	27 „ -	11.30 a.m.	·00	·00	16·6 (62)	13·3 (56)	—	—	—	—	General effluent - -	
347	27 „ -	11.45 a.m.	·00	·00	16 6 (62)	13·3 (56)	—	—	—	—	Final effluent - - -	
348	27 „ -	11.50 a.m.	·00	·00	16·6 (62)	12·7 (55)	—	—	—	—	„ „ - - -	
	1902.											
466	4th February	Noon, Monday to 11 a.m. Tues.	·15 S.R.	·00	—	—	—	—	—	—	—	
467	5th „	Noon, Tues. to 11 a.m. Wed.	·00	·00	—	—	—	—	—	—	—	
468	6th „	Noon, Wed. to 11 a.m. Thurs.	·00	·00	—	—	—	—	—	—	—	

NOTTINGHAM SEWAGE FARM.

(EFFLUENTS.)

Number of Sample.	Number of times the Sewage has passed through the Soil.	Area of Plot or Plots sewaged at the time of drawing Sample.	Length of time these Plots had been sewaged previously to drawing Sample.	Nature of Crops grown on Plots.	Remarks.
		Acres.			
11	Once	15·5	12 days, day and night sewage.	Fallow - -	This plot was sewaged continuously by night only since Oct. 10th up to Nov. 23rd, and since then, received both day and night sewage.
12	,,	a 13·0 b 10·5 c 11·25	a 7 days, night sewage only. b 15 days, night sewage only. c 15 days, night sewage only.	,, - - -	Plots sewaged for 12 hours by night.
14	,,	15·5	7 days	,, - -	After Dec. 5th this plot only received night sewage, resting during the day.
15	,,	a 13·0 b 10·5 c 11·25	a 14 days, night sewage only. b 22 days, night sewage only. c 22 days, night sewage only.	,, - - -	Plots sewaged for 12 hours by night only.
16	,,	12·0	42 days, day sewage only.	,, -	Plots sewaged for 12 hours by day.
17	,,	a 13·0 b 10·5 c 11·25	a 21 days, night sewage only. b 29 days, night sewage only. c 29 days, night sewage only.	,,	
18	,,	a 13·0 b 10·5 c 11·25	a 22 days, night sewage only. b 30 days, night sewage only. c 30 days, night sewage only.	,,	
19	,,	12·0	5 days, day sewage only.	,, - - -	Plot had 3 days' rest.
20	,,	15·5	17 days, night sewage only.	,,	
110	Once	12·0	1 day.	Mangolds - - -	Plot sewaged with day sewage for 12 hours.
111	,,	12·0	2 days.	,, - - -	Plot sewaged with day sewage for 12 hours.
113	,,	12·0	3 ,,	,, - - -	Plot sewaged with day sewage for 12 hours.
115	,,	11·25	14 ,,	Cabbage - - -	Plot sewaged with day sewage for 12 hours.
116	,,	11·25	15 ,,	,, - - -	Plot sewaged with day sewage for 12 hours.
118	,,	15·5	16 ,,	Kohl rabi - -	Plot sewaged with night sewage for 12 hours.
119	,,	11·25	16 ,,	Cabbage - - -	Plot sewaged with day sewage for 12 hours.
121	,,	—	—	—	General effluent.
330	Once	11·25	*5 days.	Cabbage - - -	Plot receiving sewage for 12 hours by day only.
331	,,	13·0	*4 ,,	Mangolds - - -	General effluents.
332	,,	—	—	—	
333	,,	—	—	—	
335	,,	11·25	*6 days.	Cabbage.	
336	,,	13·0	*5 ,,	Mangolds.	
338	,,	11·25	*7 ,,	Cabbage.	
339	,,	13·0	*6 ,,	Mangolds.	
340	,,	—	—	—	General effluents.
341	,,	—	—	—	
343	,,	11·25	*8 days.	Cabbage.	
344	,,	13·0	*7 ,,	Mangolds.	
346	,,	—	—	—	General effluent.
347	,,	11·25	*9 days.	Cabbage.	
348	,,	13·0	*8 ,,	Mangolds.	

NOTTINGHAM SEWAGE FARM.

* Comparative Effluent Samples
or Samples taken from the same plots of land.

December, 1899.	July, 1900.	September, 1901.	Remarks.
Sample No. 11 " " 14 " " 20	Sample No. 110 " " 111 " " 113	Sample No. 330 " " 335 " " 338 " " 343 " " 347	* By comparative samples is meant samples drawn from the same areas of land, and the effluents in brackets are comparable with each other so far as the area of land sewaged is concerned.
" " 12 " " 15 " " 17 " " 18	" " 115 " " 116 " " 119	" " 331 " " 336 " " 339 " " 344 " " 348	
" " 16 " " 19			

NOTTINGHAM SEWAGE FARM.

(Sewage Samples.)

No. of Sample.	Nature of Sewage.	Time taken.	Remarks.
10	Strong, dark colour -	12 (noon)	Part of the sewage gravitates to the farm and part is pumped, only the sewage pumped is screened.
13	" dye refuse -	12.15 p.m.	Screened and crude sewage.
109	Strong, dye refuse -	11.55 a.m.	Screened and crude sewage.
114	" " " -	12.15 p.m.	" " "
329	Fairly strong dye refuse	1.50 p.m.	Screened and crude sewage.
334	Strong, deep brown colour	11.35 "	" " "
337	" " " "	11.45 "	" " "
342	" " " "	11.35 "	" " "
345	" " " "	3. 0 "	" " "

SECTION VIII.

RUGBY (High Level) SEWAGE FARM.

1. Situation of farm.—New Bitton, about one mile from Rugby. (The sewage arrives at the farm in a fairly fresh condition.)

2. Total acreage of farm.—40 acres.

3. Total irrigable area.—35 acres.

4. Average area irrigated at one time.—7 acres.

5. Population draining to farm.—6,000.

6. ,, per acre irrigated.—171.

7. Gallons of sewage per head per day.—50.

8. Dry weather flow of sewage per 24 hours.—300,000 gallons.

9. Gallons of sewage (exclusive of storm water) treated per acre per 24 hours.—$42,800 = \left(\frac{300,000}{7}\right)$

10. Gallons of sewage treated per acre per 24 hours on the assumption that each acre of irrigable area is under sewage all the time. (This for purposes of comparison) $= \left(\frac{300,000}{35}\right) = 8,500$ gallons.

11. Characters of the sewage.—Mainly domestic.

12. Method of treatment.—Screening, chemical precipitation, settling tanks and surface irrigation and filtration combined (the former predominating).

13. General characters of the soil and subsoil.—Heavy loam overlying stiff clay.

14. Separate or combined sewerage system.—Partially separate.

15. The final effluent is discharged into.—River Avon.

16. Number of years farm in operation before 1900.—33 years.

A full description of Rugby (High Level) Sewage Farm will be found in Mr. Kershaw's report (Part IV., Engineering and Practical Report). It is unnecessary therefore to do more than touch very briefly on a few of the more important points described in his report.

The sewage is mainly domestic. The soil of the farm may be described as a heavy loam overlying stiff clay. The sewage is treated chemically in precipitation tanks, and afterwards on the land by surface irrigation and filtration (the former predominating). The sewerage system is partially separate. A considerable amount of subsoil water gains access to the sewers; there is not much now on the farm. There are no storm overflows. The sludge is not applied to the land on the sewage farm. The farm is underdrained; the crops grown on the farm are rye-grass, mangolds, cabbages, oats and wheat. The effluents flow into the River Avon. From Mr. Kershaw's report it appears that "*The farm has a rather steep slope towards the river, and this allows of the sewage being treated one, two or three times. After the high level sewage has been treated once or twice, it mixes with the low level sewage which comes out about half way down the farm and is treated with it. The high level sewage is thus treated as a rule three times and the low level once.*" Quoting again from Mr. Kershaw's Report: "*The total area of the farm is 40 acres, of which 35 acres are irrigable, 10 being available for the low level, and 25 for the high level sewages. This area (35 acres) deals with a sewage flow of 300,000 gallons per 24 hours from a population of 6,000 persons which is equal to 171·4 persons per irrigable acre, or about 8,500 gallons per acre. Under normal conditions about 7 acres are sewaged at once, which is equivalent to 42,850 gallons of sewage treated per acre per 24 hours.*"

The following is a summary of the several sections of the report in so far as it relates to Rugby Sewage Farm :—

1. Tabular statement and summary of the chief bacteriological results.

2. Diagram 12, illustrating the results shown in Table 19, with comments thereon.

3. Results considered in relation to Mr. Kershaw's notes.

4. Results in relation to tests other than the B. enteritidis sporogenes test.

5. Results of the examination of additional samples of mixed effluent and brook water, subsoil water, and street washings.

6. General conclusions.

Addendum A.—Comparative records as regards (1) the "gas," and (2) B. enteritidis sporogenes tests of samples obtained from Rugby as well as other sewage farms.

Addendum B.—Comparative records as regards (1) the "gas"; (2) B. enteritidis sporogenes; (3) neutral red broth; and (4) litmus milk tests of samples obtained from Rugby as well as other sewage farms.

Addendum C.—Additional bacteriological notes.

Addendum D.—Mr. Kershaw's abridged notes to accompany bacteriological data.

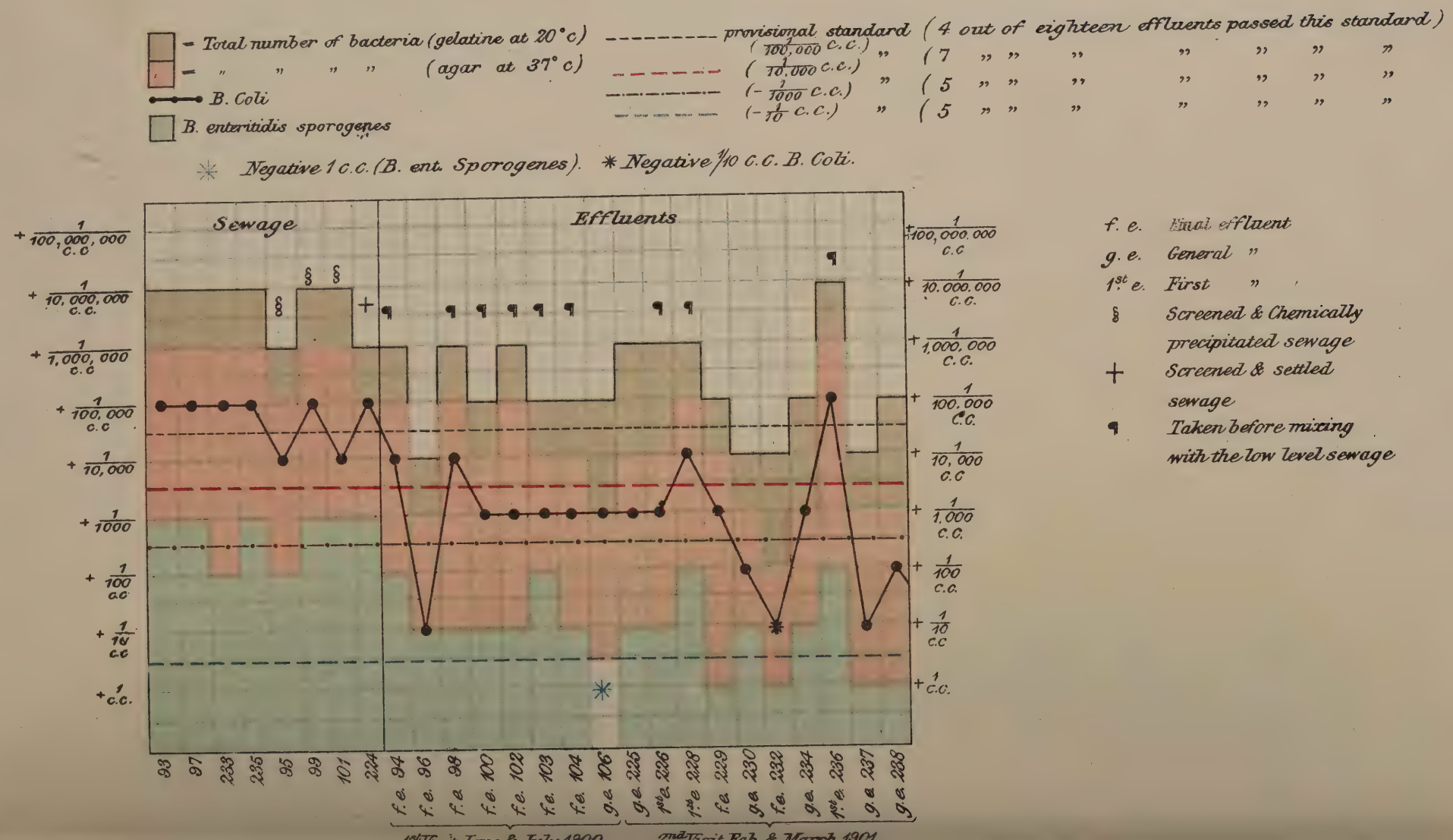
1. *Tabular statement and summary of the chief bacteriological results.*

The following table (Table 19) shows, as regards the total number of bacteria, B. coli and spores of B. enteritidis sporogenes, the results of the bacteriological examination of eight samples of sewage and eighteen samples of effluent :—

Table 19.—Showing, as regards the total number of bacteria, B. coli, and spores of B enteritidis sporogenes, the results of the bacteriological examination of sewage and effluents obtained from Rugby sewage farm.

Description of the Sample.	Total Number of bacteria per c.c.		Number of B. coli (or closely allied forms) per c.c.	Number of Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in milk culture) per c.c.	
	Gelatine at 20° C.	Agar at 37° C.			
1.	2.	3.	4.	5.	
93 Crude sewage - - - 11 a.m., 19th June 1900.	21,400,000	3,820,000	At least 100,000 -	+ ·001, – ·0001 c.c. At least 1,000 but lessthan 10,000.	
97 Crude sewage - - - 1.45 p m., 25th June 1900.	47,700,000	4,700,000	- ditto - -	- ditto - ditto.	
233 Crude sewage - - - 11.15 a m., 6th Mar. 1901.	21,500,000	3,520,000	- ditto - -	+ ·01, – ·001 c.c. At least 100 but less than 1,000.	
235 Crude sewage - - - 11.10 a.m., 11th Mar. 1901.	38,500,000	5,400,000	- ditto - -	+ ·001, – ·0001 c.c. At least 1,000 but less than 10,000.	
95 Chemically precipitated sewage. 11.15 a.m., 20th June 1900.	1,750,000	275,000	At least 10,000 -	+ .01, – ·001 c.c. At least 100 but less that 1,000.	
99 Screened, settled and precipitated sewage. 12 noon, 27th June 1900.	42,200,000	6,140,000	At least 100,000 -	+ ·001, – ·0001 c.c. At least 1,000 but less than 10,000.	
101 Screened, settled and precipitated sewage. 10.30 a.m., 22nd July 1900.	14,700,000	1,560,000	10,000 not 100,000 -	- ditto - ditto.	
224 Settled sewage - - - 4 p.m., 18th Feb. 1901.	7,300,000	820,000	At least 100,000 -	- ditto - ditto.	
Averages - -	24,381,250	3,304,375	[Ratio cols. 2 to	3=3·6 : 1.]	
94 Final effluent - - - 1 p.m , 19th June 1900.	3,090,000	588,000	At least 10,000 -	+ ·01, – ·001 c.c. At least 100 but less than 1,000.	1st visit, June and July 1900.
96 Final effluent - - - 12.15 p.m., 20th June 1900.	23,000	4,500	At least 10 but less than 100.	+ ·1, – ·01 c.c. At least 10 but less than 100.	
98 Final effluent - - - 3.15 p.m., 25th June 1900.	2,030,000	350,000	At least 10,000 -	- ditto - ditto.	
100 Second or final effluent - 2.5 p.m., 27th June 1900.	124,000	22,000	At least 1,000 but less than 10,000.	- ditto - ditto.	
102 Second or final effluent - 12.15 p m., 22nd July 1900.	1,060,000	109,000	At least 1,000 -	+ ·1 c.c. At least 10.	
103 Final effluent - - - 12.15 p.m., 3rd July 1900.	390,000	34,000	- ditto - -	+ ·01, – ·001 c.c, At least 100 but less than 1,000.	
104 Final effluent - - - 12 p.m., 4th July 1900.	193,000	28,000	- ditto - -	+ ·1, – ·01 c.c. At least 10 but less than 100.	
106 General effluent - - - 11.15 a.m., 9th July 1900.	164,000	8,100	- ditto - -	None in 1 c.c.	
225 General effluent - - - 5 p.m., 18th Feb. 1901.	1,240,000	44,000	- ditto - -	+ ·1, – ·01 c.c. At least 10 but less than 100.	2nd visit, February and March 1901.
226 First field effluent - - 12 p.m., 20th Feb. 1901.	3,660,000	42,000	- ditto - -	- ditto - ditto.	
228 First field effluent - - 10.45 a.m., 26th Feb. 1901.	5,020,000	564,000	At least 10,000 -	+ ·01, – ·001 c.c. At least 100 but less than 1,000.	
229 Final effluent - - - 11.45 a.m., 26th Feb. 1901.	640,000	15,700	At least 1,000 -	+ 1, – ·1 c.c. At least 1 but less than 10.	
230 Final and general effluent - 10.40 a.m., 27th Feb. 1901.	93,000	5,200	At least 100 - -	+ ·1, – ·01 c.c. At least 10 but less than 100.	
232 Final and general effluent - 12 p.m., 5th Mar. 1901.	38,000	900	None in ·1 c.c. -	+ 1, – ·1 c.c. At least 1 but less than 10.	
234 Final and general effluent - 12.45 p.m., 6th Mar. 1901.	144,000	3,300	At least 1,000 -	+ ·1, – ·01 c.c. At least 10 but less than 100.	
236 First field effluent - - 12.30 p.m., 11th Mar. 1901.	12,040,000	2,064,000	At least 100,000 -	+ ·01, – ·001 c.c. At least 100 but less than 1,000.	
237 Final and general effluent - 1.15 p.m., 11th Mar. 1901.	69,000	1,600	At least 10 but less than 100.	+ 1, – ·1 c.c. At least 1 but less than 10.	
238 Final and general effluent - 11.30 a.m., 13th Mar. 1901.	259,000	8,600	At least 100 -	- ditto - ditto.	
Averages, inclusive of first field effluents	1,682,055 [93% reduction]	216,272 [93% reduction]	[Ratio cols. 2 to	3=7·7 : 1.]	
Averages, exclusive of first field effluents	637,133 [97% reduction]	81,526 [97% reduction]	[Ratio cols. 2 to	3=7·8 : 1.]	

Diagram 12 shewing as regards (1) total number of bacteria, (2) B. Coli, (3) Spores of B. enteritidis sporogenes the results of the bacteriological examination of samples of sewage & effluent obtained from Rugby sewage farm.



Brief summary of the results shown in Table 19 :

Crude sewage, settled sewage, and chemically precipitated sewage :—

The samples presented the usual biological characters of sewage. Thus, the total number of bacteria in nearly all the samples was over ten million (gelatine at 20° C.) and between one and ten million (agar at 37° C.) per c.c. With two exceptions (10,000), B. coli numbered at least 100,000 per c.c. The number of B. enteritidis sporogenes was 1,000 in six samples and 100 in two samples.

Effluents :—

Total number of bacteria (gelatine at 20° C.) per c.c.—Four samples contained more than 10,000, but less than 100,000 micro-organisms. In seven samples, the number lay between 100,000 and 1,000,000. Seven samples contained over 1,000,000 but less than 10,000,000. (Provisional standard less than 100,000 per c.c.)

Total number of bacteria (agar at 37° C.) per c.c.—One sample contained 900 bacteria per c.c. Six samples contained over 1,000 but less than 10,000. In six samples the number lay between 10,000 and 100,000. Four samples contained more than 100,000 but less than 1,000,000. One sample contained over 2,000,000. (Provisional standard less than 10,000 per c.c.)

B. coli (and closely allied forms) per c.c.—One sample contained no B. coli in 0·1 c.c. In two samples the number was at least 10 but less than 100. In nine samples the number was at least 1,000. Three samples contained 10,000, and one sample 100,000. (Provisionial standard less than 1,000 per c.c.)

Spores of B. enteritidis sporogenes per c.c.—One sample gave a negative result with 1 c.c. In four samples the number was at least 1 but less than 10. One sample contained at least 10. In eight samples the number was at least 10 but less than 100. Four samples contained at least 100 but less than 1,000. (Provisional standard less than 10 per c.c.)

2. *Diagram* 12, *illustrating the results shown in Table* 19, *with comments thereon.*

The results are shown in graphic form in Diagram 12.

By referring to Diagram 12 it will be seen that certain horizontal lines are drawn indicating provisional standards (non-drinking-water streams).

All samples, which, according to these standards, did not fulfil the following requirements would be tentatively condemned :—

(1.)	Total number of bacteria (gelatine at 20° C.)	Less than 100,000	per c.c.
(2.)	,, ,, (agar at 37° C.)	Less than 10,000	
(3.)	B. coli - - - - - -	Less than 1,000	
(4.)	B. enteritidis sporogenes - - -	Less than 10	

As regards (1.) four out of 18 effluents (four out of 15, excluding the first field effluents) proved satisfactory.

,, ,, (2.) seven out of 18 effluents (seven out of 15, excluding the first field effluents) proved satisfactory.

,, ,, (3.) five out of 18 effluents (five out of 15, excluding the first field effluents) proved satisfactory.

,, ,, (4.) five out of 18 effluents (five out of 15, excluding the first field effluents) proved satisfactory.

Obviously, the majority of the effluents were not altogether satisfactory, but it should be added that a fair proportion of the samples either "passed" or came within measurable distance of "passing" the suggested standards.

Taking the B. enteritidis sporogenes results as a ready means of gauging the degree of biological purification effected by the land treatment, it is to be noted that while the sewage contained from 100 to 1,000 spores per c.c. the effluent varied as follows :—Four samples (two of them first field effluents) were undeniably bad (at least 100 in 1 c.c.). Five samples were satisfactory (less than 10 per c.c.). Nine samples (one of them a first field effluent) occupied an intermediate position (at least 10 but less than 100 per c.c.). So that it may be said that the majority of the effluents were at least from ten to one hundred times better than the original sewage.

3. *Results considered in relation to Mr. Kershaw's notes.**

From Mr. Kershaw's notes, it appears that sample 98 was obtained from the same plot as No. 94, after the plot had had three days' rest, and was drawn for the purpose of ascertaining the effect of rest. It is probable, however, that the rest was too short to influence to any material extent the biological results. At all events, the results of the bacteriological examination of samples 94 and 98 gave very similar results. The unsatisfactory biological quality of these two effluents may possibly be attributed to the fact that crude sewage, which had neither passed through the settling tanks nor been chemically treated, was being applied to the land at the time that the samples were taken. It is important to note that Mr. Kershaw says that "a large amount of subsoil water gains access to the older sewers." On the farm itself, however, but little subsoil water gains access to the effluent drains. Samples 226, 228, and 236, which yielded (particularly 236) bad results, were termed by Mr. Kershaw "first field effluents." The variable character of the different effluents does not seem always capable of being sufficiently explained either by the fact that some were final and others general effluents, or that the sewage was in some cases passed once and in others twice through or over the soil.† Samples 94, 98, 100, 102, 103, 104, 226, 228, 236, were taken *before mixing with the low level sewage.* This is an unusual course to adopt, and is accounted for by the general lie of the irrigable land (*see* Mr. Kershaw's report). The results almost seem to indicate that, under certain circumstances, this may be a useful procedure. The mixture, it is to be noted, is passed over a plot of land before gaining access to the river. The effluents above referred to seem on an average to be somewhat worse than the rest of the samples. Samples 94, 96, 98, 100, 102, 103, 104, 229, 232, were final effluents, and samples 106, 225, 230, 234, 237 and 238 general effluents.

4.—*Results considered in relation to tests other than the B. enteritidis sporogenes test.*

So far chief stress has been laid on the results obtained by the B. enteritidis sporogenes test. As regards other tests, it is to be noted that the average total number of bacteria in the sewage and effluents was as follows :—

——	Gelatine at 20° C. Number of Microbes per c.c.	Agar at 37° C. Number of Microbes per c.c.	Ratio.
Sewage - - . - -	24,381,250	3,304,375	3·6 to 1
Effluents (inclusive of first field effluents).	1,682,055 [93% reduction.]	216,272 [93% reduction.]	7·7 to 1
Effluents (exclusive of first field effluents).	637,133 [97% reduction.]	81,526 [97% reduction.]	7·8 to 1

Unquestionably these results represent a high percentage degree of purification in the effluent as compared with the sewage, but when the actual number of bacteria remaining in the effluents is so great, too much reliance must not be placed on percentage purification. The average numbers in the effluent are considerably in excess of the standards suggested, viz., less than 100,000 (gelatine at 20° C.) and less than 10,000 (agar at 37° C.) bacteria per c.c. It is, however, worth noting that the reduction in the number of bacteria capable of growing at blood heat (37° C.) was greater than that effected in the total number of microbes (gelatine at 20° C.).

The B. coli results were unsatisfactory, but not perhaps to a conspicuous extent, since, although only 5 out of 18 effluents (5 out of 15 excluding first field effluents) passed the suggested standard, nine additional samples came within measurable distance of passing this standard.

* Addendum D, page 151.

† Although the effluents represent a mixture of surface and percolation effluents, the wide range of the temperatures (*see* Mr. Kershaw's notes) would seem to indicate that the effluents were mainly surface effluents. (*See also* striking comparison between surface and percolation effluents throughout the year as given in Mr. Kershaw's report.)

In the table and diagram illustrating Appendix III. (page 196), the results as regards the "gas" and B. enteritidis sporogenes tests are brought into comparison. Of 17 (15 excluding first field effluents) effluents, nine passed the former and five the latter test.

In the table and diagram illustrating Appendix IV. (page 203), the "gas," B. enteritidis sporogenes, neutral-red broth and litmus milk tests are compared. In this comparative series, however, only three samples of effluent from Rugby are included, the majority of samples being obtained from Aldershot Camp Farm.

Indol test (indol in broth cultures, 5 days at 37° C.).

Sewages { Sample 93, ,, 97, ,, 99, ,, 224, ,, 233, ,, 235 } + ·00001 c.c.
Sewages { ,, 95 + ·0001 c.c.

Effluents { Sample 236 + ·00001 c.c.
Effluents { Samples 94, 98, 225, and 228 + ·0001 c.c.
Effluents { ,, 96, 226, 229, 234, and 238 + ·001 c.c.
Effluents { ,, 100, 230, 232, and 237 + ·01 c.c.

As judged by this test, the majority of the effluents were not altogether satisfactory. As the standard suggested is a negative result with $\frac{1}{1000}$ c.c.; only about 28 per cent. of the effluents passed this standard. Nevertheless, 64 per cent. (approximately) either passed or came within measurable distance of passing this standard.

When it is remembered that the method of treatment at Rugby consists chiefly of surface irrigation over clay land, the general bacteriological results must be regarded as decidedly good.

5. *Results of the bacteriological examination of additional samples of street "washings," brook water, mixed brook water and effluent, and subsoil water.*

The results of the examination of these samples is shown in Table 20.

TABLE 20.—Showing the results of the bacteriological examination of samples of street water, brook water, effluent, subsoil water, etc., obtained from Rugby sewage farm.

Description of the Sample.	Total Number of bacteria per c.c.		Number of B. coli (or closely allied forms) per c.c.	Number of Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in milk culture) per c.c.
	Gelatine at 20° C.	Agar at 37° C.		
96A. Street water from separate system, 20th June 1900.	15,900,000	94,000	10,000 [Indol + ·0001 c.c.]	+ ·1, – ·01 c.c. At least 10 but less than 100.
105. River Avon above effluent outfall. 9th July 1900.	156,000	7,100	At least 100	Negative 10 c.c.
06. Effluent, 9th July 1900 -	164,000	8,100	At least 1,000	Negative 1 c.c.
108. River Avon + effluent, 9th July 1900. About 330 yards below 106*.	51,000	3,500	At least 10	Negative 10 c.c.
227. Subsoil water, 25th February 1901.	33,000	1,520	1 not 10 [Indol + 1 c.c.]	+ 10 c.c., – 1 c.c. None in 1 c.c.
231. Street "washings," 4th March 1901.	930,000	12,400	1,000 [Indol + ·001 c.c.]	+ ·01, – ·001 c.c. At least 100 but less than 1000.
239. Same source as 227, 14th March 1901.	—	310	1 not 10 [Indol + 1 c.c.]	– 1 c.c. None in 1 c.c.

* Volume of effluent to River Avon about 1 : 30 normally.

Samples 96A, 105, 106, 108, 227, 231, yielded the following results as regards the "gas" test ("gas" in gelatine "shake" cultures in 24 hours at 20° C.):— + ·01, – ·001 c.c.; + 1, – ·1 c.c.; + ·1, – ·01 c.c.; + 1, – ·1 c.c.; + 1, – ·1 c.c.; negative ·1 c.c. respectively.

Samples 231 and 239 yielded the following results as regards the neutral-red broth test (greenish yellow fluorescence in neutral-red broth in 24 hours at 37° C.) :— + ·01 —·001 c.c. ; + 1 c.c. respectively.

Sample 231 yielded the following result as regards the litmus milk test (acid clot in litmus milk in 24 hours at 37° C.) :— + ·01, — ·001 c.c.

It is to be noted that samples 96A and 231 (street "washings"), especially the former, yielded very bad results. However, the number of bacteria growing in agar at 37° C., as compared with gelatine at 20° C., was relatively small. In sewage, the ratio is a close one. Both these samples proved fatal to rodents on subcutaneous injection. (Addendum C.)

The samples of subsoil water (227 and 239),* although containing a rather large number of bacteria, yielded very few B. coli (+1 c.c. ; —·1 c.c.) and sample 227 contained no spores of B. enteritidis sporogenes even in 10 c.c. and sample 239 none in 1 c.c.

As regards sample 105† it appears from Mr. Kershaw's notes that the sample, although collected above the high level farm effluent outfall, was collected about two miles below the low level sewage farm effluent outfall. This doubtless accounts for the sample being nearly as impure as the effluent itself (106). Sample 108, collected about 330 yards below sample 106, was considerably purer than the Avon River above the effluent outfall. The volume of the effluent to the river water is about 1 : 30 normally.

6.—*General Conclusions.*

It is certain that none of the effluents were in a fit state to be turned into a drinking water‡ stream, and the majority of them could not be considered as altogether satisfactory for discharge even into non-drinking water rivers. But the fact that some of the effluents were so pure (relatively speaking)§ suggests that land of the kind available at Rugby, if it is not overworked, is not incapable of yielding a uniformly good effluent ; if, in short, the area of land available for irrigation purposes is in proper proportion to the amount of sewage to be treated. In conclusion, the *majority* of the effluents may be said either to have passed or have come within measurable distance of passing the standards provisionally suggested ; therefore, with justice, it cannot be contended that a heavy loam over stiff clay is wholly unsuited for sewage purification purposes. Percentage, as opposed to actual purification, is misleading, but the remarkable percentage improvement in the effluents as compared with the sewage is worth noting, although it must be admitted that the actual results were not altogether satisfactory. For statistical information see tabular statement at the beginning of this Report, Section VIII.

Addendum A.—*Comparative records as regards* (1) *the "gas" test, and* (2) *B. enteritidis sporogenes tests of samples obtained from Rugby as well as other sewage farms.*

These results are shown in the table and diagram, illustrating Appendix III. (page 196), and they include all the samples (from other sewage farms as well as Rugby) which were examined by both of these tests. Altogether, 194 samples are dealt with, of which 24 were obtained from Rugby sewage farm. Of the 17 effluents (15 excluding first field effluents) 9 passed the gas test, and 5 the B. enteritidis sporogenes test.

---

* From Mr. Kershaw's notes it appears that these samples were drawn from a well (20 ft. deep, containing 10 ft. of water) on the farm. The land is sewaged to within about 40 ft. of the well. From the situation and surroundings of this well, Mr. Kershaw considers that sewage pollution might occur. Under the circumstances the biological results are surprisingly good.

† The usual biological impurity of the river water into which effluents are discharged must inevitably influence the question of the final selection of reasonable biological standards of purity to be attained by the effluents themselves antecedent to discharge into such rivers.

‡ It must be remembered that my standards suggested for effluents destined to discharge into non-drinking water streams are so moderate in character, that even if an effluent were diluted at least ten to one-hundred times with *pure* river water, the mixture would constitute a liquid potentially dangerous for drinking purposes, and no responsible bacteriologist would consider it as safe for domestic use.

§ For example, seven out of fifteen effluents contained less than 10,000 microbes per c.c. (agar at 37° C.). The average number in these samples was less than one-half the standard limit of 10,000 per c.c.

Addendum B.—*General comparison as regards* (a) *the gas;* (b) *B. enteritidis sporogenes;* (c) *neutral-red broth; and* (d) *litmus milk tests of sample obtained from Rugby as well as other sewage farms.*

These results are shown in the table and diagram, illustrating Appendix IV. (page 203), and they include all the samples (63 in number) which were examined by all (with a few exceptions) of these tests. Most of the samples, however, were obtained from Aldershot Camp sewage farm, and the Rugby samples were only four in number. Three of these were effluents, and taking the tests in the above order, 3, 3, 3, and 1, respectively successfully "passed" the standards set up for these four tests.

Addendum C.—*Additional bacteriological notes.*

Streptococci.

Streptococcus 13 was isolated from $\frac{1}{1000}$ c.c. of effluent 94. Surface agar plate culture incubated at 37° C.

Morphology.—Very short chains of cocci. Stains well by Gram's method.

Gelatine streak cultures (20° C.).—Very minute transparent-looking colonies.

Agar streak cultures (37° C.).—Culture made from a broth culture (7 days old) did not show any growth. The experiment was repeated with a like negative result.

Broth cultures (37° C.).—Diffuse but not abundant cloudiness.

Litmus milk cultures (37° C.).—Strong acidity but no clot.

Streptococcus 19 was isolated from $\frac{1}{100}$ c.c. of effluent 226. Agar plate culture incubated at 37° C.

This microbe produced diffuse cloudiness in broth cultures. Examined microscopically the chains of cocci were found to be of medium length.

Streptococcus 20.—Was isolated from $\frac{1}{10000}$ c.c. of effluent 230. Broth culture incubated at 37° C. and subsequent plating.

Morphology.—A streptococcus forming very long chains. Stains well by Gram's method.

Agar plate cultures (37° C.).—Minute transparent-looking colonies. Under a low power of the microscope the colonies show coarse wavy granulation and at the edge of the colonies the separate loops of cocci are visible.

Gelatine plate cultures (20° C.).—No growth after one week.

Agar streak cultures (37° C.).—Minute transparent-looking colonies.

Gelatine streak cultures (20° C.).—No appreciable growth after one week.

Broth cultures (37° C.).—The liquid remains quite transparent; at the foot of the tube a white woolly mass collects.

Litmus milk cultures (37° C.).—Acidity, but no clot.

Remarks.—Not found to be pathogenic to guinea-pigs.

Streptococcus 21.—Was isolated from $\frac{1}{10000}$ c.c. of effluent 233. Surface gelatine plate cultures, incubated at 20° C. In broth cultures, growth occurred at the foot of the tube as a viscous white mass, the liquid remaining quite clear. Examined microscopically, the chains of cocci were of medium length.

Animal Inoculation Experiments.—Three guinea-pigs (a, b, and c) were subcutaneously inoculated with (a) 4 c.c. of effluent 225; (b) 10 c.c. of effluent 232; (c) 10 c.c. of effluent 237. They all (a, b, and c) recovered from the effects of the injection.

Two guinea-pigs (a and b) were subcutaneously inoculated with 1 c.c. (a) and 2 c.c. (b) of sample 96 A (street "washings"). Both showed a strong local reaction. (a) guinea-pig recovered, but (b) guinea-pig suffered from ulceration of the abdominal wall and died on the fourth day.

Two guinea-pigs (a and b) were subcutaneously inoculated with 2 c.c (a) and 4 c.c. (b) of sample 224 (sewage). In the case of (b) the sewage was first (before the inoculation) heated to 80° C. for 10 minutes. (b) Guinea-pig recovered from the effects of the injection; (a) guinea-pig died after some weeks from pseudo-tuberculosis (B. pseudo-tuberculosis of A. Pfeiffer).

A guinea-pig was subcutaneously inoculated with 10 c.c. of effluent 230. The animal seemed to be but little, if at all, affected. Death took place on the fourteenth day, but probably not from the effects of the injection.

A guinea-pig was subcutaneously inoculated with 4 c.c. of sample 231 (street "washings"). It died on the second day, doubtless from the effects of the injection.

Two guinea-pigs (a and b) were subcutaneously inoculated with 3 c.c. (a) and 6 c.c. (b) of sample 233 (sewage). In the case of (b) the sewage was first (before the inoculation) heated to 80° C. for 10 minutes. (a) Guinea-pig died on the second day; (b) guinea-pig recovered completely from the effects of the injection.

A guinea-pig was subcutaneously inoculated with 10 c.c. of effluent 234. The animal was seemingly but slightly affected. 39 days after the injection, it was killed and examined. The organs seemed to be normal but at the site of the inoculation a small abscess was found. Cultures made from this yielded a proteus-like microbe. This microbe was actively mobile, liquefied gelatine, gave "gas" in gelatine shake cultures, and produced clotting and peptonisation in milk cultures.

Two guinea-pigs (a) and (b) were subcutaneously inoculated with 2 c.c. (a) and 8 c.c. (b) of sample 235 (sewage). In the case of (b) the sewage was first (before inoculation) heated to 80° C. for 10 minutes. Both the animals died.

ADDENDUM D.—*Mr. Kershaw's abridged notes to accompany bacteriological data.**

RUGBY HIGH LEVEL SEWAGE FARM.

Additional Notes on Samples.

Sample No. 94.—This effluent was from crude sewage which had neither passed through the settling tanks nor been chemically treated.

Effluent had a slight sewage smell. The rye grass was a fair crop, and ready for cutting. (Third crop.)

Sample No. 96.—This effluent in common with all other effluents treated twice (unless otherwise mentioned), after passing over the first field mixes with the precipitated sewage (from the low level tanks), further down the farm, and this mixture is then passed over another plot before reaching the river.

Sample No. 98.—Effluent off rye grass after 3 days' rest: *i.e.*, off the same plot as No. 94 and therefore comparable with it, for the purpose of ascertaining the effects of rest.

Sample No. 99a. This effluent was obtained from oats which had previously been cut to make ensilage.

Sample No. 100.—Very slight sewage smell.

Sample No. 105.—River Avon water taken above effluent outfalls. River very low, apparently in good condition. Bed of river clean.

Note.—The low level sewage farm effluent outfall discharges into the river about two miles above the point where this sample was taken.

Sample No. 107.—River water and effluent taken after mixing.

Sample No. 108.—River water and effluent taken 250 yards below sample No. 107.

Sample No. 226b.—River water and effluent taken 200 yards below effluent outfalls, clear green colour. River high.

Sample No. 227.—Water drawn from well at manager's house on farm, well 20 ft. deep, 10 ft. of water. Well sunk into the Lias Clay. Water clear and effervescing. The sample was drawn from the pump after three minutes pumping.

Sample No. 230a.—River water above effluent outfalls rather cloudy, due to flood water coming down. See Note as to sample No. 105.

Sample No. 231.—"Street washings" taken from a surface water drain; not much vehicular traffic in the street, surface of street very clean from previous heavy showers This sample would include water from the front roofs of houses.

Sample No. 234a—River water taken below effluent outfalls, river very high and in flood, a cloudy sample.

Sample No. 234. - General effluent, faint yellow colour, no smell, effluent on mixing with river water turned a red-brown colour.

Sample No 238a.—River water and effluent taken ten yards below effluent outfall, clear, no smell, rive still fairly high.

Sample No. 239.—Well water taken from same source as No. 227.

Note.—The land is sewaged within about 40 feet of this well, and it appears quite probable that the well may have been polluted.

---

* In a few instances samples are referred to in this addendum concerning which there are no bacteriological records. These were extra samples collected by Mr. Kershaw for chemical analysis.

RUGBY HIGH LEVEL SEWAGE FARM.

Domestic Sewage.

Number of Sample.	Date of Drawing Sample.	Time of Day.	Rainfall day previous to drawing Sample.	Rainfall day of drawing Sample.	Atmospheric Temperature time of drawing Sample.		Temperature of Sample.		Maximum Temperature during the 24 hours.		Minimum Temperature during the 24 hours.		Humidity (9 a.m.)	Dissolved Oxygen in Sample.	Brief Description of Sample.	Remarks.
	1900:		Inches.	Inches.	°C.	°F.	°C.	°F.	°C.	°F.	°C.	°F.		c.c.		
93	19 June	11 a.m.	·00	·01	20·0	(68)	13·3	(56)	23·3	(74)	10·5	(51)	—	—	Crude sewage.	
94	19 „	1 p.m.	·00	·01	21·6	(71)	15·0	(59)	23·3	(74)	10·5	(51)	—	—	Final effluent.	
95	20 „	11.15 a.m.	·01	·11	20·5	(69)	15·0	(59)	20·5	(69)	7·7	(46)	—	—	Screened, settled and precipitated sewage.	
96	20 „	12.15 p.m.	·01	·11	20·0	(68)	21·1	(70)	20·5	(69)	7·7	(46)	—	—	Final effluent.	
97	25 „	1.45 „	·40	·47	20·5	(69)	13·3	(56)	20·5	(69)	9·4	(49)	—	—	Crude sewage.	
98	25 „	3.15 „	·40	·47	14·4	(58)	13·8	(57)	20·5	(69)	9·4	(49)	—	—	Final effluent - - -	Mean daily maximum temperature, 19·6 °C. (67·4 F.).
99	27 „	12 (noon)	·00	·00	14·4	(58)	13·3	(56)	20·5	(69)	7·2	(45)	—	—	Screened, settled and precipitated sewage.	Mean daily minimum temperature 8·3 °C. (47 F.).
99A	27 „	1.15 p.m.	·00	·00	17·2	(63)	17·2	(63)	20·5	(69)	7.2	(45)	—	—	First field effluent.	Mean daily rainfall, ·065 in.
100	27 „	2.5 „	·00	·00	15·5	(60)	15·0	(59)	20·5	(69)	7·2	(45)	—	—	Second or final effluent.	
101	22 July	10.30 a.m.	·00	·06	18·8	(66)	14·4	(58)	22·2	(72)	10·0	(50)	—	—	Screened, settled and precipitated sewage.	For the period June 18th to July 8th, 1900.
101A	22 „	11.30 „	·00	·06	20·0	(68)	18·8	(66)	22·2	(72)	10·0	(50)	—	—	First field effluent.	
102	22 „	12.15 p.m.	·00	·06	16·1	(61)	17·2	(63)	22·2	(72)	10·0	(50)	—	—	Second or final effluent.	
103	3 „	12.15 „	·06	·00	17·7	(64)	17·7	(64)	20·5	(69)	6·6	(44)	—	—	Final effluent.	
104	4 „	12 (noon)	·00	·00	17·7	(64)	17·2	(63)	21·6	(71)	11·1	(52)	—	—	Final effluent.	
105	9 „	11 a.m.	·00	·00	17·7	(64)	16·1	(61)	—		—		—	—	River Avon water.	
106	9 „	11.15 „	·00	·00	20·0	(68)	16·1	(61)	—		—		—	—	§General effluent - -	§ By "general" effluent is meant a mixture of two or more finally treated effluents on leaving the farm.
107	9 „	11.30 „	·00	·00	17·2	(63)	16·1	(61)	—		—		—	—	River water and effluent.	
108	9 „	12 (noon)	·00	·00	17·2	(63)	16·1	(61)	—		—		-	—	River water and effluent.	
1901:	1901:															
224	18 February	4 p.m.	—	†·05 (s.)	4·4	(40)	5·5	(42)	6·6	(44)	1·6	(29)	92	—	Screened and settled sewage.	† (s.) signifying snow.
225	18 „	5 „	—	†·05 (s.)	4·4	(40)	3·3	(38)	6·6	(44)	1·6	(29)	92	—	General effluent.	

226	20 February	12 (noon)	·005 (a.)	·00	3·8	(39)	2·2	(36)	3·3	(38)	6·1	(21)	83	1·75	First field effluent.	
226A	21 ,,	11.15 ,,	·00	·07	1·6	(35)	2·2	(36)	5·0	(41)	0·5	(33)	89	4·50	General effluent.	
226B	21 ,,	11.30 ,,	·00	·07	1·6	(35)	2·2	(36)	5·0	(41)	0·5	(33)	89	8·00	River water and effluent.	
226C	22 ,,	11.33 ,,	·07	·01	5·5	(42)	4·4	(40)	7·7	(46)	3·3	(38)	85	4·00	General effluent.	
227	25 ,,	12 (noon)	·00	·00	10·0	(50)	7·7	(46)	10·5	(51)	3·8	(39)	79	4·25	Well water.	
228	26 ,,	10.45 a.m.	·00	·13	5·5	(42)	4·4	(40)	6·6	(44)	3·3	(38)	92	0·25	First field effluent.	Mean daily maximum temperature 8·2° C. (46·75° F.)
229	26 ,,	11.45 ,,	·00	.13	5·5	(42)	5·5	(42)	6·6	(44)	3·3	(38)	92	2·5	Final effluent.	Mean daily minimum temperature, 1·4° C. (34·6° F.)
230	27 ,,	11.40 ,,	·13	·00	6·6	(44)	5·5	(42)	6.6	(44)	3·3	(38)	92	—	Final and general effluent.	Mean daily humidity 87·08.
230A	1 March	11 ,	·07	·14	8·8	(48)	5·5	(42)	10·0	(50)	0·5	(31)	79	6·50	River water.	Mean daily rainfall, ·056 in.
231	4 ,,	10 ,,	·30	·06	6·1	(43)	3·8	(39)	8·8	(46)	7·7	(46)	85	—	Street washings.	
232	5 ,,	12 (noon)	·06	·14	11·1	(52)	8·3	(47)	11·1	(52)	3·3	(38)	73	3·50	Final and general effluent.	For the period February 18th to March 14th, 1901.
233	6 ,,	11.15 a.m.	14	·03	5·0	(41)	8·3	(47)	6·1	(43)	3·3	(38)	84	—	Crude sewage.	
234	6 ,,	12.45 p.m.	·14	·03	5·0	(41)	5·5	(42)	6·1	(43)	3·3	(38)	84	—	Final and general effluent.	
234A	6 ,,	12.50 ,,	·14	·03	5·0	(41)	4·4	(40)	6·1	(43)	3·3	(38)	84	—	River water and effluent.	
234B	7 ,,	10.45 a.m.	·03	·22	5·0	(41)	4·4	(40)	7·7	(46)	2·7	(37)	92	—	Final and general effluent.	
234C	8 ,,	11.15 ,,	·22	·02	5·0	(41)	5·5	(42)	7·7	(46)	0·0	(32)	78	—	Final and general effluent.	
234D	9 ,,	11.50 ,,	·02	·00	5·0	(41)	5·0	(41)	8·8	(48)	3·8	(25)	84	—	Final and general effluent.	
235	11 ,,	11.10 ,,	·00	·00	5·5	(42)	7·7	(46)	11·1	(52)	1·6	(35)	100	—	Crude sewage.	
236	11 ,,	13.30 p.m.	·00	·00	6·6	(44)	5·5	(42)	11·1	(52)	1·6	(35)	100	—	First field effluent.	
237	11 ,,	1.15 ,,	·00	·00	7·7	(46)	6·1	(43)	11·1	(52)	1·6	(35)	100	4·25	Final and general effluent.	
238	13 ,,	11.20 a.m.	·005	·00	3·3	(38)	6·6	(44)	4·4	(40)	1·1	(34)	84	4·00	Final and general effluent.	
238A	13 ,,	11.30 ,,	·005	·00	3·3	(38)	6·1	(43)	4·4	(40)	1·1	(34)	84	6·25	River water and effluent.	
238B	14 ,,	11.5 ,	·00	·00	5·0	(41)	6·1	(43)	—		—		92	—	First field effluent.	
238C	14 ,,	11.45	·00	·00	5·0	(41)	5·5	(42)	—		—		92	—	Final and general effluent.	
239	14 ,,	10 a.m.	·00	·00	4·4	(40)	7·7	(46)	—		—		92	3·00	Well water.	
472	18 February	Noon, Monday to 11 a.m. Tuesday.	·00	·00	—		—		—		—		—	—	Screened and settled sewage.	24 hours samples.
473	19 ,,	Noon, Tuesday to 11 a.m. Wednesday.	·00	·00	—		—		—		—		—	—	Screened and settled sewage.	24 hours samples.
474	20 ,,	Noon, Wednesday to 11 a.m. Thursday.	·00	·00	—		—		—		—		—	—	Screened and settled sewage.	24 hours samples.

RUGBY HIGH LEVEL SEWAGE FARM.

Domestic Sewage.

Number of Sample.	Number of Times the Sewage was passed through or over the Soil.	Area of Plot or Plots sewaged at the time of drawing Sample.	Length of Time these Plots had been sewaged previously to drawing Sample.	Nature of Crops grown on Plots.	Remarks.
		Acres.			
94	Once	2·25	10 days	Ryegrass - - - -	*Filtration effluent.
96	Twice	1·70	5 days	,, - - -	Surface and filtration effluen
98	Once	2·25	6 hours	,, - - -	* ,, ,, ,,
99a	,,	1·5	5 days	Young oats (just cut) -	* ,, ,, ,,
100	Twice	{1·5 ·5}	,, ,,	Ryegrass - - -	* ,, ,, ,,
101a	Once	0·5	5 hours	Young oats (just cut) -	* ,, ,, ,,
102	Twice	0·75	3 days	Ryegrass - - -	* ,, ,, ,,
103	,,	{1·0 0·75}	1 day 4 days	Cut oats and Ryegrass	* ,, ,, ,,
104	,,	{1·0 0·75}	2 ,, 5 ,,	,, ,, ,,	* ,, ,, ,,
106	,,	—	—	—	General effluent.
225	Twice	6·0	—	Arable and ryegrass -	General effluent (surface filtration).
226	Once	5·75	4 ,,	Arable - - - -	*Filtration effluent.
226a	Twice	—	—	Arable and ryegrass -	General ,,
226c	,,	—	—	,, ,, ,, -	,, ,, (surface filtration).
228	Once	4·75	1 day	Arable - - - -	*Filtration effluent.
229	Twice	{4·75 1·25}	2 days	Arable and ryegrass -	,, and surface effluen
230	,,	—	—	,, ,, ,, -	General effluent ,, ,,
232	,,	—	—	,, ,, ,, -	,, ,, ,, ,,
234	,,	—	—	,, ,, ,, -	,, ,, ,, ,,
234b	,,	—	—	,, ,, ,, -	,, ,, ,, ,,
234c	,,	—	—	,, ,, ,, -	,, ,, ,, ,,
234d	,,	—	—	,, ,, ,, -	,, ,, ,, ,,
236	Once	4·75	2 ,,	Arable - - - -	*First effluent ,, ,,
237	Twice	—	—	,, - - - -	General ,, ,, ,,
238	,,	{4·0 1·90}	2 ,,	,, - - - -	,, ,, ,, ,,
238b	Once	4·90	5 ,,	,, - - - -	*First ,, ,, ,,
238c	Twice	—	—	,, - - - -	General ,, ,, ,,

Note.—All effluents to which an asterisk (*) is prefixed wer taken before mixing with the low level sewage.

RUGBY SEWAGE FARM

Sewage Samples.

Number of Sample.	Time sample was taken.	Nature of Sewage.	Remarks.
93	11.0 a.m.	Crude sewage - - -	This sewage waa applied to the land before being chemically treated, or passed through the settling tanks.
95	11.15 ,,	Screened and chemically precipitated sewage.	Alumino Ferric, sulphate of iron and lime solutions were used—Alumino Ferric alone at night.
97	1.45 p.m.	Crude sewage - - -	As No. 93.
99	Noon.	Screened and chemically precipitated sewage.	Chemically precipitated and screened sewage—as No. 95
101	10.30 a.m.	,, ,, ,,	As No. 97.
224	4.0 p.m.	Screened and settled sewage—dilute.	Not chemically treated. *Note* None of the sewage was being chemically treated at this visit.
233	11.15 a.m.	Crude sewage—dilute -	As Nos. 93 and 97. An oily film on surface.
235	11.10 ,,	Crude sewage—strong -	As Nos. 93, 97, and 233, contained a good deal of sediment.
472 473 474	24 hrs. samples		

SECTION IX.

SANDHURST, LINDFIELD, LUTON, WORSLEY, HEMSWORTH, AND DERBY COUNTY ASYLUM SEWAGE FARMS.*

As the samples obtained from these places were not very numerous, the results have been grouped together in the following table :—

TABLE 21.—Showing the results of the bacteriological examination of samples of sewage, effluents and other liquids obtained from Sandhurst, Lindfield, Luton, Worsley, Hemsworth, and Derby County Asylum Sewage Farms.

SANDHURST SEWAGE FARM.

Description of the Sample.	Total Number of Bacteria per c.c.		Number of B coli. (or closely allied forms) per c.c.	Number of Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in milk culture) per c.c.
	Gelatine at 20° C.	Agar at 37° C.		
1.	2.	3.	4.	5.
61 *Sandhurst* settled sewage - 4th April 1900.	21,600,000	1,510,000	At least 100,000 - [Indol + ·00001 c.c.]	+ ·01, – ·001 c.c. At least 100 but less than 1,000.
62 First field effluent - - 4th April 1900.	2,230,000	66,000	1,000 not 10,000 - [Indol + ·0001 c.c.]	+ ·1, – ·01 c.c. At least 10 but less than 100.
63 Final effluent - - - 4th April 1900.	338,000	115,400	1,000 not 10,000 - [Indol + ·0001 c.c.]	+ ·01, – ·001 c.c. At least 100 but less than 1,000.

LINDFIELD SEWAGE FARM.

79 *Lindfield* final effluent - 21st April 1900.	42,000	510	100 not 1,000 - - [Indol + ·01 c.c.]	+ 1, – ·1 c.c. At least 1 but less than 10.
80 Settled sewage - - - 21st April 1900.	102,400,000	13,360,000	At least 100,000 - [Indol + ·00001 c.c.]	+ ·001, – ·0001 c.c. At least 1,000 but less than 10,000.
91 Settled sewage - - - 7th June 1900.	55,200,000	8,700,000	At least 100,000 - [Indol + ·00001 c.c.]	- ditto - ditto.
92 Final effluent - - - 12th June 1900.	292,000	46,000	1,000 not 10,000 - [Indol + ·001 c.c.]	+ ·1, – ·01 c.c. At least 10 but less than 100.

LUTON SEWAGE FARM.

240 *Luton* spring water from watercress beds. 19th March 1901.	1,030	105	None in 1 c.c - [Indol + 1 c.c.]	Negative, 10 c.c.
241 Mixture springs from watercress beds. 19th March 1901.	66,000	860	10 not 100 - - [Indol + ·01 c.c.]	+ 10 c.c. – 1 c.c. None in 1 c.c.
242 Well water, 20 feet deep - 19th March 1901.	40,000	410	At least 10 - - [Indol + ·1 c.c.]	Negative, 10 c.c.
243 Spring water in watercress beds. 27th March 1901.	570	33	None in 1 c.c.] [Indol, neg 1 c.c.)	- ditto.
244 Well water corresponding to 242. 27th March 1901.	800	266	None in 1 c.c. - [Indol + 1 c.c.],	- ditto.
244A Crude sewage - - - 27th March 1901.	90,600,000	15,540,000	At least 100,000 - [Indol + ·00001 c.c.]	+ ·001, – ·0001 c.c. At least 1,000 but less than 10,000.
409 Luton filtration effluent - - 5th November 1901.	16,120,000	4,172,000	At least 100,000 - [Indol + ·00001 c.c.]	+ ·01, – ·001 c.c. At least 100 but less than 1,000.
410 Luton well water. 7th November 1901. Same well as 242 and 244.	52,000	2,090	1 not 10 - - - [Indol, neg. 1 c.c.]	Negative 1 c.c.

* Notes relating to Dr. Vivian Poore's experimental garden at Andover are also included.

Samples 409, 411, 412, 413, 414, 441 and 442 gave the following results as regards the *neutral red broth test* (24 hours at 37° C.); + ·0001 c.c.; + ·1, – ·01 c.c.; + ·00001 c.c.; + ·00001 c.c.; + ·00001 c.c.; + ·00001 c.c.; + ·00001 c.c.; and + ·00001 c.c., respectively.

Samples 409, 411, 412, 413, 414, 441 and 442 gave the following results as regards the "*gas*" *test* ("gas" in gelatine shake cultures, 24 hours at 20° C.); + ·001 c.c.; – 1 c.c.; + ·001, – ·0001 c.c.; + ·001, – ·0001 c.c.; + ·001 – ·0001 c.c.; + ·001, – ·0001 c.c.; + ·001 – ·0001 c.c.; and + ·01, – ·001 c.c., respectively.

LUTON SEWAGE FARM—*continued.*

Description of the Sample.	Total Number of bacteria per c.c.		Number of B. coli. (or closely allied forms) per c.c.	Number of Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in milk culture) per c.c.
	Gelatine at 20° C.	Agar at 37° C.		
1.	2.	3.	4.	5.
411 Luton settled sewage - - 7th November 1901.	27,800,000	3,400,000	At least 100,000 - [Indol + ·00001 c.c.]	+ ·001, – ·0001 c.c. At least 1,000 but less than 10,000.
412 Luton filtration effluent - 7th November 1901.	11,020,000	1,568,000	Less than 10,000 - [Indol + ·0001 c.c.]	+ ·01, – ·001 c.c. At least 100 but less than 1,000.
413 Luton settled sewage - - 11th November 1901.	9,800,000	2,290,000	At least 100,000 - [Indol + ·0001 c.c.]	+ ·01, – ·001 c.c. At least 100 but less than 1,000.
414 Luton filtration effluent - 11th November 1901.	8,800,000	2,310,000	At least 10,000 - [Indol + ·0001 c.c.]	+ ·01, – ·001 c.c., At least 100 but less than 1,000.
441 Luton settled sewage - - 12th December 1901.	—	–	—	+ ·001, – ·0001 c.c. At least 1,000 but less than 10,000.
442 Luton filtration effluent - 12th December 1901.	—	—	—	+ ·01, – ·001 c.c. At least 100 but less than 1,000.

WORSLEY SEWAGE FARM.

277 *Worsley* crude sewage - 13th May 1901.	48,400,000	7,380,000	At least 100,000 - [Indol + ·00001 c.c.]	+ ·01, – ·001 c.c. At least 100 but less than 1,000.
278 Final effluent - - - 13th May 1901.	240,000	59,000	100 not 1,000 - - [Indol + ·001 c.c.]	+ 1, – ·1 c.c. At least 1 but less than 10.
279 Liquor from peat land (not effluent). 15th May 1901.	310	65	Negative $\frac{1}{10}$ c.c. - [Indol + ·1 c.c.]	None in 1 c.c.
280 Effluent from peat land - 15th May 1901.	400,000	142,000	At least 1,000 - [Indol + ·001 c.c.]	+ 1, – ·1 c.c. At least 1 but less than 10.
281 Crude sewage - - - 20th May 1901.	790,000	350,000	At least 10,000 - [Indol + ·0001 c.c.]	+ ·1, – ·01 c.c. At least 10 but less than 100.
282 Effluent from peat land - 20th May 1901.	125,000	25,000	At least 1,000 - [Indol + ·001 c.c.]	+ 1, – ·1 c.c. At least 1 but less than 10.
283 Peat water not effluent - 20th May 1901.	11,200	1,000	At least 100 - - [Indol + ·01 c.c.]	- ditto - ditto.
284 Brook water above effluent outfall. 20th May 1901.	304,000	41,500	At least 100 - - [Indol + ·01 c.c.]	- ditto - ditto.
285 Crude sewage - - - 28th May 1901.	60,000 000	19,560,000	At least 100,000 - [Indol + ·00001 c.c.]	+ ·01, – ·001 c.c. At least 100 but less than 1,000.
286 Effluent peat land - - 28th May 1901.	670,000	17,000	At least 1,000 - [Indol + ·001 c.c.]	No record.
287 Effluent gravel and sand grit. 28th May 1901.	1,340,000	9,200	Less than 1,000 - [Indol + ·01 c.c.]	+ 1, – ·1 c.c. At least 1 but less than 10.
290 Peat water - - - - 28th May 1901.	244,000	300	1 not 10 - - - [Indol + ·1 c.c.]	+ ·1, – ·01 c.c. At least 10 but less than 100.

HEMSWORTH SEWAGE FARM.

291 *Hemsworth* settled sewage - 4th June 1901.	44,000,000	6,120,000	At least 100,000 - [Indol + ·00001 c.c.]	+ ·01, – ·001 c.c. At least 100 but less than 1,000.
292 Corresponding effluent - 4th June 1901.	5,040,000	292,000	100 not 1,000 - - [Indol + ·001 c.c.]	- ditto - ditto.
293 Crude sewage - - - 5th June 1901.	48,400,000	14,960,000	At least 100,000 [Indol + ·00001 c.c]-	+ ·001, – ·0001 c.c. At least 1,000 but less than 10,000.
294 Final effluent - - - 5th June 1901.	5,280,000	540,000	At least 10,000 [Indol + ·0001 c.c.]-	+ ·1, – ·01 c.c. At least 10 but less than 100.

DERBY COUNTY ASYLUM SEWAGE FARM.

Description of the Sample.	Total Number of bacteria per c.c.		Number of B. coli. (or closely allied forms) per c.c.	Number of Spores of B. enteritidis sporogenes (Klein's 'enteritidis change" in milk culture) per c.c.
	Gelatine at 20° C.	Agar at 37° C.		
1.	2.	3.	4.	5.
295 Derby County Asylum crude sewage. 11th June 1901.	11,100,000	4,680,000	At least 100,000 - [Indol + ·00001 c.c.]	+ ·1, – ·01 c.c. At least 10 but less than 100.
296 Corresponding effluent - 11th June 1901.	2,580,000	382,000	1,000 not 10,000 - [Indol + ·001 c.c.]	- ditto - ditto.
297 Final effluent - - - 12th June 1901.	2,540,000	388,000	At least 1,000 - [Indol + ·00001 c.c.]	- ditto - ditto.
298 Same, farther down ditch - 12th June 1901.	420,000	64,000	At least 1,000 - [Indol + ·001 c.c.]	- ditto - ditto.

SANDHURST SEWAGE FARM.

It is unnecessary here to enter into any description of this farm, as Mr. Kershaw has prepared some brief notes on the subject to accompany the bacteriological report. (Addendum A., page 164.)

Three samples (61, 62 and 63) were examined. The first (61) was a sample of settled sewage, and the results were very similar to those usually obtained in the bacteriological analysis of sewage. Sample 62 was a first field effluent, and 63 a final effluent. Neither of these samples could be regarded as quite satisfactory, according to my suggested standards, but the samples showed a high percentage degree of purification, as compared with the settled sewage.

LINDFIELD SEWAGE FARM.

Mr. Kershaw's notes on this farm accompany the bacteriological report, and so no further description need here be given. (Addendum A., page 164.)

Four samples were examined; two of settled sewage (80 and 91), and two of final effluent (79 and 92). The sewage yielded exceptionally high figures as regards the total number of microbes present and the effluents were in comparison remarkably good. Particularly was this the case as regards No. 79. It appears, however, that this sample was diluted with subsoil water. It is worth noting that the soil is clayey, and liable to crack badly. Further, that Mr. Kershaw classed both of the effluents as having a slight sewage smell. The bacteriological results are therefore all the more striking.

LUTON SEWAGE FARM

It will be seen from Mr. Kershaw's report (Part IV. Engineering and Practical Report) that the surface soil rests on chalk, and that the effluent soaks into the chalk. Mr. Kershaw, however, by dint of much ingenuity and labour, managed to obtain samples representing chalk filtration effluents by digging a deep hole and making therefrom a lateral burrow into the substance of the chalk. Previously he collected samples from a well and from springs in the immediate vicinity of the farm, which, owing to the direction taken by the underground water might be expected to be influenced by the percolation of the effluent through the chalk (*see* Mr. Kershaw's report and plan).

The well waters, 242, 244 and 410 all yielded negative results as regards the B. enteritidis sporogenes test. Two out of the three samples contained B. coli, and a large total number of bacteria. The water could not be regarded as safe for drinking purposes.

As regards the spring water, samples 240 and 243 were comparable, being both drawn from the same place. They contained no spores of B. enteritidis sporogenes, even in 10 c.c., and no B. coli in 1 c.c. Sample 241

(mixture of springs from watercress beds) was less satisfactory, as positive results were obtained both with the B. coli and B. enteritidis sporogenes tests, with ·1 c c. and 10 c.c. respectively.

The chalk filtration effluents (409, 412, 414, and 442) obtained by Mr. Kershaw by artificial means, yielded very bad results on bacteriological analysis, and were not bacteriologically remote from samples of untreated sewage.

WORSLEY SEWAGE FARM.

In his report on this farm, Mr. Kershaw is careful to draw a distinction between the northern portion of the farm, consisting of a gravel and sand soil, where most of the sewage is treated, and the southern part, which is covered with a deep bed of peat.

Three samples of crude sewage were examined (277, 281 and 285). Of these 281 was peculiar as being an exceptionally weak sewage, judged by biological analysis.*

Samples 279, 283, and 290 were representative of water draining away from the peat and were not contaminated, so far as could be judged by admixture with the effluent. Sample 279 was of great purity, but 283 and 290 were by no means so pure, and possibly they may have received some drainings from land at one time sewaged.

Sample 287, derived from the gravel and sand portion of the farm above referred to was in most respects a good effluent.

Samples 278, 280, 282, and 286, are of especial interest, as they represent effluents from peaty land. They yielded good results as regards the B. enteritidis sporogenes test, but the total number of bacteria and number of B. coli was not wholly satisfactory. Nevertheless the results, considered in relation to the peaty characters of the soil on the farm, are surprisingly good, and do not, considered from the bacteriological point of view, altogether bear out the view so generally held, that peat is quite unsuitable for sewage purification purposes.

Sample 284 was from the Parrin brook (above the effluent outfall), which, according to Mr. Kershaw's notes (page 167), was in a very bad condition. The bacteriological results showed that it resembled a sewage effluent of medium quality.

Samples 277, 285, 278, 280, and 287 were also examined by the neutral red broth, litmus milk, and gas tests (*see* Appendix IV., page 203).

HEMSWORTH SEWAGE FARM.

(Domestic sewage.)

It is apparent from Mr. Kershaw's report† that the conditions are most unsuitable on this farm for the proper purification of sewage. The land consists of heavy clay and is almost impervious, and the underdraining probably only serves by means of cracks and fissures to allow the sewage readily to escape without really passing over or through the soil. Moreover, as Mr. Kershaw points out, the conformation of the farm and the fall of the ground militate against effective treatment of the sewage. Lastly, the amount of sewage to be treated is out of all proportion to the irrigable area.

Four samples were examined, one of settled sewage (291), one of crude sewage (293), and two effluents (292 and 294).

As regards the effluents, both were unsatisfactory as regards the total number of bacteria present and number of spores of B. enteritidis sporogenes. Effluent 292, but not effluent 294, passed the standard set up for the B. coli test.

DERBY COUNTY ASYLUM SEWAGE FARM.

(Domestic sewage.)

According to Mr. Kershaw's report,† the conditions on this farm for the proper purification of sewage were of an unsatisfactory nature. The soil is clay, and much of the sewage appears to escape, by means of cracks and fissures in the soil, into the underdrains without undergoing any proper treatment.

---

* Since the above was written, Dr. McGowan has informed me that this sample had an acid reaction, which persisted even after boiling.

† Part IV. Engineering and Practical Report.

Four samples were examined, one of sewage (295) and three of effluents (296, 297, 298). The effluents were all unsatisfactory, but 298 collected lower down the ditch than 297, showed signs of improvement.

Samples 295, 296, 297 and 298 were also examined by the neutral red broth, litmus milk, and gas (*see* Appendix IV., page 203).

ANDOVER.*

Two samples were collected from Dr. Vivian Poore's experimental garden at Andover.

One (415) was a sample of shallow well water. The well is in the middle of the garden and was constructed in 1891. The surrounding land (1 acre. 1 rood, 7 poles) has been manured for over 14 years with the ordure and house refuse of about 100 persons. The water can only enter the well through the bottom.†

The results were as follows :—

Total number of bacteria	gelatine at 20° C. - - -	1,400	per c.c.
	agar at 37° C. - - -	280	

B. coli per c.c. :—At least one, but less than 10 in 1 c.c.

Indol test :—Positive result, 1 c.c. ; negative result, 0·1 c.c.

B. enteritidis sporogenes test :—Negative result, 1 c.c.

"Gas" in gelatine "shake" cultures (24 hours at 20° C.) :—Negative result, 1 c.c.

Neutral red broth test :—Negative result, 0·1 c.c.

Under the circumstances described above, the results were surprisingly good, but the presence of B. coli in 1 c.c. shewed that contamination, presumably of animal sort, was not altogether absent.

The other sample (416) was a sample of rain-water from an artificial filter. The filter was constructed on the Venetian principle.‡

The results were as follows :—

Total number of bacteria	gelatine at 20° C. - - - -	25	per c.c.
	agar at 37° C. - - - - -	7	

B. coli, indol, "gas" and B. enteritidis sporogenes tests :—Negative results with 1 c.c.

Neutral red broth test :—Negative result with 0·1 c.c.

The results were obviously of a very satisfactory nature, but it must be remembered that in judging waters from the point of view of potability, a more elaborate method of analysis (Pasteur filter-brushing method) is necessary than was carried out in the present instance before final conclusions can be drawn.

---

* *See* Addendum A., page 164.

† ‡ For fuller details Dr. Poore's book must be consulted.—"The Earth in relation to the Preservation and Destruction of Contagia."

ADDENDUM A.—Mr. Kershaw's Abridged Notes to accompany Bacteriological Data.

HEMSWORTH SEWAGE FARM.

(Domestic Sewage.)

Number of Sample.	Date of drawing Sample.	Time of day.	Rainfall day previous to drawing Sample.	Rainfall day of Drawing Sample.	Air Temperature time of Drawing Sample.	Temperature of Sample.	Maximum Temperature during the 24 hours.	Minimum Temperature during the 24 hours.	Humidity 9 a.m.	Dissolved Oxygen in Sample.	Brief description of Sample.	Remarks.
	1901.				°C. °F.	°C. °F.	°C. °F.	°C. °F.				
291	June 4th -	10.15 a.m. -	·00″	·04″	17·2 (67)	(63)	25·5 (78)	11·6 (53)	68	—	Settled Sewage -	Soapy sewage, after passing through tanks.
292	,, ,, - -	11.30 ,, -	,,	,,	15·5 (70)	(60)	,, ,,	,, ,,	,,	—	Final Effluent -	Turbid, sewage smell.
293	,, 5th - -	10.45 ,, -	·04″	·00	13·3 (60)	(56)	23·3 (74)	8·3 (47)	63	—	Crude Sewage -	Soapy—alumino ferric being used.
294	,, ,, - -	11.15 ,, -	,,	,,	16·6 (61)	(62)	,, ,,	,, ,,	,,	—	Final Effluent -	Cloudy, strong sewage smell.

Mean daily Maximum Temp. 26·6 °C. (80° F.)
,, ,, Minimum ,, 10·1 °C. (50.3° F.)
,, ,, Humidity - - - 63·75
,, ,, Rainfall - - ·01 in.
For the period June 3rd to June 6th, 1901.
NOTE.—Samples which may have been affected by rainfall are *underlined*.

EFFLUENTS.

No. of sample.	Number of times the Sewage has passed through the soil.	Area of plot or plots sewaged at the time of drawing Sample.	Length of time these plots had been sewaged.	Nature of crops grown on plots.	Remarks.
292	Twice - - - - - -	About ·25 acres - - -	5 days - - - - - -	No crops - - - - -	Effluent a dirty muddy colour, after passing through two successive clay beds.
294	,, - - - - - - -	,, ,, - - - - -	6 days - - - - - -	,, - - - - - -	Effluent turned a milky colour on entering ditch, after passing through two clay beds.

DERBY COUNTY ASYLUM SEWAGE FARM.

(Domestic Sewage).

Number of Samples.	Date of drawing Sample.	Time of Day.	Rainfall day previous to drawing Sample.	Rainfall day of drawing Sample.	Air Temperature time of drawing Sample.	Temperature of Sample.	Maximum Temperature during the 24 hours.	Minimum Temperature during the 24 hours.	Humidity (9 a.m.)	Dissolved Oxygen in Sample.	Brief Description of Sample.	Remarks.
	1901.				°C. °F.	°C. °F.	°C. °F.	°C. °F.				
295	June 11th - -	10.55 a.m.	·00″	·00″	14·4 (58)	17·7 (64)	22·2 (72)	9·4 (49)	81	—	Screened Sewage.	Soapy appearance.
296	,, ,,	12.0 (noon)	,,	,,	14·4 (58)	10·0 (50)	,, ,,	,, ,,	,,	—	Final Effluent.	Turbid, no smell.
297	,, 12th - -	11.15 a.m.	·00″	·00″	13·3 (56)	10·0 (50)	20·0 (68)	11·1 (52)	76	—	,, ,,	Dirty colour, suspended matter.
298	,, ,, - -	11.45 a.m.	,,	,,	13·3 (56)	11·1 (52)	,, ,,	,, ,,	,,	—	,, ,,	Same effluent as No. 297 but taken 300 yds. further down ditch.
299	,, 13th - -	10.55 a.m.	·00″	·07″	8·8 (48)	11·1 (52)	13·3 (56)	5·0 (41)	81	—	,, ,,	Yellow colour.
300	,, ,, - -	11.30 a.m.	,,	,,	10·0 (50)	11·1 (52)	,, ,,	,, ,,	,,	—	,, ,,	Same effluent as No. 299 but taken 300 yds. further down ditch.
301	,, ,, - -	12.0 (noon).	,,	,,	10·0 (50)	10·0 (50)	,, ,,	,, ,,	,,	—	,, ,,	,, ,, ,, 600 yds.

Mean Maximum Temperature 18·3° C. (65° F.)
,, Minimum ,, 8·3° C. (47° F.)
,, Humidity - - - - 80·2.
,, Rainfall - - - - - ·014in.
For the period June 10th to June 14th, 1901.

Number of Sample.	Number of times the Sewage has passed through the soil.	Area of plot or plots sewaged at the time of drawing Sample.	Length of time these plots had been sewaged previously to drawing Sample.	Nature of crops grown on plots.	Remarks.
296	Once - - - - -	About 1 acre - - -	6 hours - - - -	Mangolds (ridged) - -	Effluent appeared to be insufficiently filtered, *i.e.*, a lot of suspended matter.
297	,, - - - - - -	,, ,, - - -	1 day - - - -	,, ,, - -	,, ,, ,, ,, ,, some partially digested hay in sample having apparently reached the drains through cracks.*
298	,, - - - - - -	,, ,, - - -	,, - - - -	,, ,, - -	As No. 297, but taken 300 yards further down the effluent ditch to show increased aeration (if any). The ditch alluded to contained nothing but effluent.
299	,, - - - - - -	,, ,, - - -	6 hours - - - -	Turnips (just up) - -	Effluent yellow colour—no smell.
300	,, - - - - - -	,, ,, - - -	,, - - - -	,, ,, - -	Taken in the same way as No. 299 at the same place. Less suspended matter than in No. 299 owing to settlement in ditch.
301	,, - - - - -	,, ,, - - -	,, - - - -	,, ,, - -	Sample same as No. 299, but taken 600 yards further down the ditch.

* The farmyard manure was turned on from 4. p.m. to 6.30 p.m. the previous evening, probably accounting for the presence of the suspended matter alluded to above, and showing the presence of large cracks in the soil, through which some of the sewage escapes to the drains practically untreated.

(Domestic Sewage and Refuse from Straw-Plait Industry.)

No. of Sample.	Date of drawing Sample.	Time of drawing Sample.	Rainfall day of drawing Sample.	Air Temperature time of drawing Sample.	Temperature of Sample.	Brief description of Sample.	Remarks.
240	March 19th 1901 - -	Noon - - -	Slight rain and snow	3·3° C. = 38° F.	7·7° C. = 46° F.	Spring water	Spring water taken from watercress beds below the Sewage Farm. A clear sample.
241	March 19th 1901 - -	12.15 p.m. - -	Slight rain and snow	3·8° C. = 39° F.	8·3° C. = 47° F.	Spring water	Mixture of springs feeding watercress beds. Water clear.
242	March 19th 1901 - -	12.45 p.m. - -	Slight rain and snow	3·3° C. = 38° F.	7·7° C. = 46° F.	Well water	* Well water from cottages below farm. Well 20 feet deep, 2 feet water. Water only fairly clear.
243	March 27th 1901 - -	3.30 p.m. - -	Slight rain	3·3° C. = 38° F.	7·7° C. = 46° F.	Spring water	This sample was drawn from the same place as No. 240.
244	March 27th 1901 - -	3.45 p.m. - -	Slight rain	2·7° C. = 37° F.	7·7° C. = 46° F.	Well water	This sample was drawn from the same well as No. 242. Water in well 2 feet deep, and water contained some sediment.
244A	March 27th 1901 - -	3.0 p.m. - -	Slight rain	1·1° C. = 34° F.	10·0° C. = 50° F.	Crude sewage	A good deal of dye refuse, blue black colour.
409	November 5th 1901 - -	3.30 p.m. - -	Some rain	4·4° C = 40° F.	10·0° C. = 50° F.	Filtration effluent	This effluent was collected from a pit dug in the chalk. The sewage had previously passed over a length of rye grass of about 30 feet, finally filtering through from 2 feet 6 inches to 3 feet of loose rotten chalk into the pit. Slight sewage smell; turbid.
410	November 7th 1901 - -	11.15 a.m. - -	No rain	8·8° C. = 48° F.	10·0° C. = 50° F.	Well water	From same well as Nos. 242 and 244. Water in well 1 foot 3 inches deep. Sample a chalky blue colour, containing some finely-divided suspended matter.
411	November 7th 1901 - -	1.0 p.m. - -	No rain	10·0° C. = 50° F.	11·1° C. = 52° F.	Settled sewage	This sample was taken from small recess at the head of the pit immediately before filtering through. Apparently a weak sewage, containing some dye refuse.
412	November 7th 1901 - -	1.15 p.m. - -	No rain	10·0° C. = 50° F.	9·4° C. = 49° F.	Filtration effluent	The same as No. 411, but after passing vertically through about 3 feet 6 inches of loose chalk. Turbid; slight sewage smell.
413	November 11th 1901 - -	12.30 p.m. - -	No rain	12·2° C = 54° F.	11·6° C. = 53° F.	Settled sewage	This sample was taken from the same place as No. 411. Some dye refuse.
414	November 11th 1901 - -	1.0 p.m. - -	No rain	12·2° C. = 54° F.	10·0° C. = 50° F.	Filtration effluent	Taken in a similar way to No. 412. Turbid chalky colour.
441	December 12th 1901 - -	3.30 p.m. - -	Very heavy rain during drawing of sample	8·3° C. = 47° F	5·0° C. = 41° F.	Settled sewage	Taken in the same way as No. 413. Contained dye refuse.
442	December 12th 1901 - -	3.40 p.m. - -	Very heavy rain during drawing of sample	7·2° C. = 45° F.	3·8° C. = 39° F.	Filtration effluent	Rye grass immediately above pit last sewaged on December 11th 1901:—Resulting effluent from No. 441 through about 3 feet 6 inches of loose chalk. This effluent took about 1½ minutes to pass through the chalk.

DATA CONCERNING THE LUTON SEWAGE FARM.

Population draining to farm - - - - - -	About 38,500.
Water supply per head - - - - - - -	About 24 gallons.
Average sewage flow per 24 hours (including rainfall)	1,700,000 gallons.
Nature of trade refuse - - - - - - -	Bleach and dye refuse.
Treatment of sewage - - - - - - -	Screening and settling tanks, then pumped to the farm, the lift being from 42 feet to 125 feet, and run down grips between the beds on which the crops are grown, except in the case of rye grass, when it flows over the entire service.
Average annual rainfall (1888 to 1899) - - -	25·3 inches.
Sewerage system - - - - - - - -	Partially separate.
Area of crops on farm, year ending September, 1899 -	79 acres.
Principal crop - - - - - - - - -	Rye grass.

* NOTE.—This well was dry steined, and used as drinking water by two cottages. Formerly privies were used, but after a case of typhoid fever had occurred, they were converted into tub closets; the contents of these closets were, however, still used as a manure for garden crops growing in the immediate vicinity of the well.

SANDHURST SEWAGE FARM.

No. of sample.	Date of drawing sample.	Time of drawing sample	Rainfall day of drawing sample.	Air temperature time of drawing sample.	Temperature of sample.	Brief description of sample.	Remarks.
				°C. °F.	°C. °F.		
61	April 4th, 1900 - -	Noon - -	No rain. ·30 in. day previous	—	8·8 (48)	Screened and settled sewage	Rather weak.
62	,, ,, - -	1.30 p.m. -	,, ,, ,,	—	13·3 (56)	First field effluent -	A surface effluent from rye-grass, a small plot about 40 ft. long. This effluent had a sewage smell.
63	,, ,, - -	3.0 ,, -	,, ,, ,,	—	10·0 (50)	Final effluent - -	A filtration effluent after treatment through another rye-grass plot.

Data concerning Sandhurst Sewage Farm.

Area of farm	13 acres.
Nature of soil and subsoil	Similar to the Camp Farm, but of rather a better nature, and more top soil.
Population	600 to 700.
Under-drains	3 ft. deep.
Sewage flow per 24 hours	About 15,000 gallons.
Principal crops	Rye-grass and mangolds.
Method of treatment	As at the Camp Farm—passed through settling tanks (in duplicate) before coming on to the land.

LINDFIELD SEWAGE FARM.

				°C. °F.	°C. °F.		
79	May 21st, 1900 - -	3.35 p.m. -	No rain - - - -	16·6 (62)	11·6 (53)	Final effluent - -	Filtration effluent from 1·75 acre plot sown mangolds (just up). Effluent had a slight sewage smell.
80	,, ,, - -	3.50 ,, -	,, ,, - - - -	16·6 (62)	11·6 (53)	Settled sewage - -	Apparently containing a good deal of subsoil water.
91	June 12th, 1900 - -	12.55 ,, -	,, ,, - - - -	26·6 (80)	11·6 (53)	,, ,, - -	Very soapy—washing day.
92	,, ,, - -	2.20 ,, -	,, ,, - - - -	28·8 (84)	11·6 (53)	Final effluent - -	From—·75 acres osiers—filtration effluent—slight sewage smell.

Area of farm - - - - - - - 8 acres. Entire area of farm under-drained 4 ft. deep. A stiff clayey soil overlaying clay—very liable to crack. in hot weather. Sewage first passed through settling tanks before going on to the land.

ANDOVER.

				°C. °F.	°C. °F.		
415	December 13th, 1901 -	1.45 p.m. -	A slight drizzle - -	7·7 (46)	9·4 (49)	Well water - - -	From shallow well in garden. 3 ft. of water in well. Two ft. from ground level to water level. Well formed of concrete tubes.
416	,, ,, -	3.0 ,, -	,, ,, - - -	6·6 (44)	8·8 (48)	Filter water - -	Rain water from artificial filter.

NOTE :—The plots in the garden vary in size from about 12 to 21 rods, and they receive the clearings from privies of 20 cottages, or about 100 persons, which are dug in. It takes from about 6 months upwards to finish one plot according to the size. All kinds of greens are grown, and can be planted a few days after the solids have been dug in. A plot which was in process of being manured in October, 1901, will probably be manured again in 1905. There is a good depth of soil (about 4 ft.) in the garden overlying the chalk. At the time of drawing the sample from the well, solids were being trenched in about 50 ft. distant from the well itself. Total area now cultivated about 5¼ roods.

WORSLEY URBAN DISTRICT COUNCIL.

BARTON MOSS SEWAGE FARM.

(Domestic Sewage and Dye Refuse.)

Number of Sample.	Date of drawing Sample.	Time of day.	Rainfall day previous to drawing Sample.	Rainfall day of drawing Sample.	Air Temperature time of drawing Sample.		Temperature of Sample.		Maximum Temperature during the 24 hours.		Minimum temperature during the 24 hours.		Humidity (9 a.m.)	Dissolved Oxygen in Sample.	Brief Description of Sample.	Remarks.
	1901		Inches.	Inches.	°C.	°F.	°C.	°F.	°C.	°F.	°C.	°F.				
277	13 May -	11.45 a.m.	·00	·00	15·5	(60)	13·3	(56)	31·1	(88)	1·6	(35)	(58)	—	Crude sewage - - -	Mean daily maximum temperature 26·9° C. (80·55° F.).
278	13 ,, -	12.15 p.m.	·00	·00	15·5	(60)	8·8	(48)	31·1	(88)	1·6	(35)	(58)	—	Final effluent - - -	
279	15 ,, -	12 0 (noon)	·00	·00	18·3	(65)	12·2	(54)	31·6	(89)	4·4	(40)	(93)	—	Peat liquor - - - -	Mean daily minimum temperature 4·5° C. (40·11° F.).
280	15 ,, -	12.15 ,,	·00	·00	18·3	(65)	10·0	(50)	31·6	(89)	4·4	(40)	(93)	—	Final effluent - - -	
280a	15 ,, -	12.45 ,,	·00	·00	19·4	(67)	11·6	(53)	31·6	(89)	4·4	(40)	(93)	—	Brook water and effluent -	Mean daily humidity 68·5
281	20 ,, -	4.15 ,,	·00	·00	21·1	(70)	13·3	(56)	24·4	(76)	0·0	(32)	(68)	—	Crude sewage - - -	Mean daily Rainfall ·01″.
282	20 ,, -	5.30 ,,	·00	·00	20·5	(69)	13·8	(57)	24·4	(76)	0·0	(32)	(68)	—	Final effluent - - -	
283	20 ,, -	4.25 ,,	00	·00	21·1	(70)	15·5	(60)	24·4	(76)	0·0	(32)	(68)	—	Peat liquor - - -	For the period May 12th to May 29th 1901.
284	20 ,, -	4.45 ,,	·00	·00	21·1	(70)	15·0	(59)	24·4	(76)	0·0	(32)	(68)	—	Brook water - -	
285	28 ,, -	12. 0 (noon)	·04	·00	23·3	(74)	15·5	(60)	19·4	(67)	7·2	(45)	(64)	–	Crude sewage - - -	
286	28 ,, -	1.20 p.m.	·04	·00	24·4	(76)	15·5	(60)	19·4	(67)	7·2	(45)	(64)		Final effluent - - -	Note.—Samples which may have been affected by rainfall are underlined.
287	28 ,, -	1. 0 ,,	·04	·00	25·5	(78)	14·4	(58)	19·4	(67)	7·2	(45)	(64)	—	Final effluent - - -	
288	28 ,, -	12.35 ,,	·04	·00	26·6	(80)	17·7	(64)	19·4	(67)	7·2	(45)	(64)	—	Brook water - - -	
289	28 ,, -	12.45 ,,	·04	·00	26·6	(80)	17·7	(64)	19·4	(67)	7·2	(45)	(64)	—	Brook water and effluent -	
290	28 ,, -	12.15 ,,	·04	·00	24·4	(76)	15·1	(61)	19·4	(67)	7·2	(45)	(64)	—	Peat liquor - - - -	

WORSLEY.

Sewage Samples.

No. of Sample.	Nature of Sewage.	Character.	Time taken.	Remarks.
277 - - -	Containing dye refuse -	Crude sewage -	11.45 a.m.	Neither screened nor settled—dark, blackish colour.
281 - - -	,, ,, ,, -	,, ,, -	4.15 p.m.	Neither screened nor settled—dark, blackish colour.
285 - - -	,, ,, ,, -	,, ,, -	12.0 noon	Neither screened nor settled—very black looking.

* Comparative Samples

(or Samples taken from the same Plots of Land).

No. of Sample.	Remarks.
278 - - - - - -	* By comparative samples is meant samples drawn from the same areas of land and the effluents in brackets are comparable with each other so far as the area of land is concerned.
280 - - - - - -	
282 - - - - - -	
286 - - - - - -	

WORSLEY.

Effluents and Other Samples (Not Sewage).

Number of Sample.	Number of times the sewage is passed through the soil.	Area of plot or plots sewaged at the time of drawing Sample.	Length of time these plots had been sewaged previous to drawing Sample.	Nature of crops grown on plots.	Remarks.
		Acres.			
278	Once	7·50	2½ days	Rye and various coarse grasses.	Yellow colour, slight sewage smell—final effluent.
279	—	—	—	—	Liquor from peat land—yellowish colour.
280a	—	—	—	—	Brook water and effluent taken 20 yards below effluent outfall—muddy colour.
280	Once	7·50	—	Rye and coarse grass -	Yellow colour, slight smell—final effluent.
282	Once	7·50	12 hours	" " "	Reddish yellow colour sewage and iron smell—final effluent.
283	—	—	—	—	Liquor from peat land—yellow colour.
284	—	—	—	—	Brook water above effluent outfall—muddy dirty colour.
286	Once	7·50	12 hours	Rye and other grasses -	Final effluent—yellow colour, sewage smell.
287	Once	8·50	15 hours	" " "	Final effluent—yellow colour, but no smell.
288	—	—	—	—	Brook water above effluent outfall—yellowish colour.
289	—	-	—	—	Brook water and effluent taken 100 yards below effluent outfall.
290	—	—	—	—	Peat liquor, dirty yellow colour.

WORSLEY SEWAGE FARM.

Additional Notes on different Samples.

Sample No. 277.—There appeared to be a larger quantity of dye refuse in it.

Sample No. 278.—Final effluent from peat land. There was scarcely any surface soil whatever, the decayed peat forming the greater portion, in cuttings where visible, the peat at a depth of 5 to 6 feet was lying upon a layer of very fine white sand. The land sewaged had not been finally levelled, and consequently, the sewage had a tendency to pond in some parts. The plot was covered with coarse herbages, chiefly grass and water plants.

Sample No. 279.—This sample was drawn from water draining from the peat into an open ditch cut in the peat. I am unable to state definitely whether this ditch had ever been polluted by sewage or effluent. The manager informed me that it had not been, to the best of his knowledge; and judging from the appearance and position of the spot, I should say it was unlikely.

Sample No. 280a.—Brook water and effluent; the brook appeared to be in a very bad condition, both above and below the effluent outfall; the bed of the stream was covered with black mud and there was a large amount of sewage weed present. I was given to understand by the manager that another sewage farm effluent empties into this stream before it passes the Worsley. The sample was a dirty muddy colour. The effluent outfall discharges at right angles to the stream and both appeared well mixed. The brook joins the ship canal further down.

Sample No. 287.—Final effluent. This was a sample drawn from another portion of the farm, where the soil was composed of sand and gravel, but no peat, and suitable for sewage treatment. It appeared to be a fair average sample of the effluent which the better portions of the farm turn out.

CONCLUSIONS.

The most important question to be answered from the bacteriological point of view is as follows :—

1.—*Can the treatment of sewage on land so modify its biological qualities as safely to admit of the discharge of effluents from land processes into drinking water streams?*

On the basis of the results embodied in this report, with the apparent, rather than real, exception of Nottingham sewage farm*, the answer to this question is decidedly in the negative.

This conclusion is arrived at as the result of the examination of a multiplicity of samples of effluents from different kinds of land.

The results conclusively show that the treatment of sewage on land cannot be relied on *materially to modify* the potentially dangerous qualities of crude sewage.

The actual number of objectionable microbes persisting in the effluents is too great to allow of much stress being laid on the great percentage reduction effected in the total number of microbes by the land treatment, or to insure any certainty that effluents from land processes are "relatively safe." Where the microbes of recent intestinal outcome are concerned "relative safety" is a dangerous consideration to rely on.

Nevertheless, there are certain *modifying circumstances* tending toward safety which must needs be considered.

One of the most important of these is the condition of "delay." By "delay" is meant the interval which elapses between the discharge of sewage on the land and its passing away as effluent after treatment by the land.

From the epidemiological point of view, this is a point of considerable importance, because delay in the above sense is a circumstance which makes for safety. Unfortunately, there are no data available to show the "time relation" between a particular microbe passing on to the land and its reappearance in the effluent.† The question arises whether the passage of sewage microbes over or through the soil is comparable to the rate of flow of soluble substances, or whether the soil, until it has become saturated, holds back the microbes and eventually hands over, as it were, to the effluent the "bacterial value" of what it has been continuously receiving from the sewage (less a certain percentage of micro-organisms which have undergone dissolution in the process). Considering this latter view of the case, the microbes in a particular effluent need not necessarily have been derived from the *corresponding* sample of sewage. The particular problem is complicated by the fact that microbes must be multiplying as well as dying in the soil, and that we have no knowledge of the relation between the two processes. So that, when it is stated that a particular sample of sewage contained 100,000 B. coli per c.c., and that the effluent collected at such a subsequent time as to make it a *seemingly corresponding* sample contained 1,000 B. coli in 1 c.c., it must be understood that the true relation between the coli microbes in the sewage and the effluent is not necessarily known. It may be conjectured that, in the case of surface irrigation, the time relation of sewage and effluent is shorter than as regards land "filtration" processes proper.

[The terms "surface irrigation" and "filtration" in connection with sewage farms are here used in the same sense as the older terms, broad irrigation and intermittent downward filtration.]

Another point arising out of the above is the question as to how far the sewage micro-organisms of objectionable sort are likely, during retention in the soil, to be affected in their properties, vital and other. Modification of these sewage micro-organisms might occur either as the result of competition with their saprophytic neighbours derived both from the sewage and from the soil, or as the result of the exposure of such sewage micro-organisms to adverse physical conditions. When a sewage farm has been in constant operation

* The apparent rather than real exception of Nottingham sewage farm is a matter fully dealt with in Section VII.

† In a recent report to the Commission, experiments are described dealing with the inoculation of sewage with B. pyocyaneus and the subsequent isolation of this microbe from (1a) the effluent from a continuous filter; (2a) septic tank liquor; and (2b) the effluent from contact beds. (This report is included in Vol. III. of the Fourth Report of the Commission.)

for over 30 years, it must be concluded that the power of mere mechanical retention in the soil of the sewage microbes has long since reached a constant* level, and that the difference observed between the number of bacteria in the effluents and in the sewage (which may on the average represent a reduction of considerably over 90 per cent.), truly corresponds to the rate of dissolution of bacterial life. Further, that, whatever may be the rate of multiplication of the sewage microbes in the soil, this bacterial death rate always more than keeps pace with it. But, short of the destruction of life, there may be loss during their sojourn in the soil of particular *properties* originally possessed by the sewage microbes; although between crude sewage and sewage effluents I have obtained no tangible evidence of this, my recent work for the Local Government Board seemingly affords some indication of the possible truth of this hypothesis. Certainly, comparing the coli-like microbes derived from (1) fæces, (2) sewage, and (3) polluted soils and water, the great majority of those obtained from (1) fæces are apt, when subjected to certain tests, to be "strong" in the possession of positive characters; whereas no inconsiderable proportion of those isolated from (3) soils and water frequently respond "less vigorously" to the same tests. But it is difficult to say whether these differences represent a loss of attributes originally possessed by such B. coli subsequently isolated from soil and water, or whether in the case of soil and water such microbes are a coli-like bacterial flora proper to soil and water and differing in attributes and origin from the coli of direct intestinal outcome. Sewage would seem to occupy an intermediate position in this respect, but, as regards the character of the coli-microbes present in it, resembles fæces more than water and soil.

The above problems are of great importance, and are not yet solved. From the epidemiological point of view, it may be conjectured that the "nature of the treatment" in the case of land "makes for safety" more than where artificial processes of sewage disposal are concerned.

Another point to be remembered is that the B. coli test is used in routine work as indicating potential danger to health. Now B. coli, to the best of our knowledge, is a more hardy germ than either B. typhosus or the cholera vibrio. The persistence therefore of B. coli in sewage effluents is no certain proof that B. typhosus and the cholera vibrio would survive under parallel conditions. In 1898-9 I carried out some experiments on the inoculation of soil *in rure* with Koch's vibrio. My results seemed to show that the relative, if not actual, death of this microbe took place within a few days in the surface layers of the particular soil of experiment. But in some of the experiments there was evidence of the persistence for longer periods (? 20 days in one experiment and ? 40 days in another experiment) of microbes, of which the identity with Koch's vibrio was uncertain. Dr. Sidney Martin found that the life history of B. typhosus in soil was a short one; but the recent experiments of Drs. Firth and Horrocks seem to indicate that, under certain conditions and with particular soils, the enteric fever bacillus may persist for a considerable period.

In the foregoing paragraphs certain considerations of a sort likely to modify *a priori* impressions have been briefly set down. But in questions affecting possible danger to health, it is wise to preserve a wide margin of safety. It is therefore held that the treatment of sewage on land cannot be trusted so to modify the objectionable biological qualities of the sewage as safely to permit of the discharge of the sewage effluents from land processes into drinking water streams.†

In the following tables are data, abstracted from the reports on the several sewage farms, which in my view combine to afford strong presumption of the cogency of the above proposition. Table A gives details with regard to the character of the sewage, the nature of the soil, the method of treatment, and the gallons treated per acre per 24 hours. Table B supplies a summary of the bacterial records.

---

* Subject, of course, to fluctuations due to rest and many other factors.

† Dilution of effluent with river water, distance of flow between the effluent outfalls and the nearest intake for water-works purposes, and subsequent filtration at the water works, are all factors which taken separately, and the more so in conjunction, are important. Nevertheless as previously pointed out "relative safety" is a dangerous consideration to rely on where any risk of the spread of epidemic and preventable disease is concerned.

Table A.

	Characters of the sewage.	*Nature of the soil.*	*Method of treatment.*	*Gallons of sewage treated per acre per 24 hours (dry weather flow divided by average area irrigated at one time).*
ALDERSHOT CAMP	Domestic -	Sandy -	Screening, settling tanks and *land filtration*	25,000 * (8,300)
ALTRINCHAM -	Domestic -	Peaty and sandy	Settling tank and *land filtration*	46,000 (23,000)
CAMBRIDGE -	Mainly domestic	Sandy loam -	Screening, settling tank and *land filtration*	121,600 (30,400)
BEDDINGTON (Croydon)	Domestic -	Gravelly loam	Screening, *surface irrigation and a little filtration*	57,100 (9,500)
LEICESTER -	$\frac{3}{4}$ domestic $\frac{1}{4}$ trade refuse	Stiff clayey soil	Screening, settling tanks and *surface irrigation and filtration* combined	21,500 (5,370)
SOUTH NORWOOD	Domestic -	Clay soil -	Screening, settling tanks and *surface irrigation*	12,000 (4,000)
NOTTINGHAM -	$\frac{4}{7}$ domestic $\frac{3}{7}$ trade refuse	Light sandy loam	Screening (partial) and *land filtration.*	23,300 (10,750)
RUGBY - -	Mainly domestic	Heavy loam	Screening, chemical precipitation, settling tanks, *surface irrigation* and *filtration* combined	42,800 (8,500)

* *The figures in brackets refer to the gallons of sewage treated per acre per 24 hours, on the assumption that each acre of the irrigable area is under sewage all the time (dry weather flow divided by total irrigable area).*

Table B.

Sewage Farm.	Total Number of Bacteria per c.c.		Number of B. coli per c.c.	Number of spores of B. enteritidis sporogenes (Klein's "enteritidis change" in milk cultures) per c.c.
	Gelatine at 20°C.	Agar at 37°C.		
Aldershot Camp effluents [Domestic sewage; sandy soil; screening, settling tanks and land filtration; gallons of sewage treated per acre per 24 hours, 25,000.]	183,266 (average number, exclusive of the new land effluents, A and B)	37,308	Varied usually from 100 to 10,000 per c.c. At least 1,000, but less than 10,000 in 1 c.c. would be a fair statement of the average number.	Varied usually from at least 1 (but less than 10), to at least 100 (but less than 1,000) per c.c. At least 10, but less than 100, in 1 c.c. would be a fair estimate of the average number.
	930,273 (average number, inclusive of all the effluents)	153,630		
Altrincham effluents - - [Domestic sewage; peaty and sandy soil; settling tank and land filtration; gallons of sewage treated per acre per 24 hours, 46,000.]	363,400 (average number)	7,275 (average number)	Varied usually from 100 to 1,000 per c.c.	Varied usually from 1 to 10 per c.c.
Cambridge effluents - - [Mainly domestic sewage; sandy loam; screening, settling tank and land filtration; gallons of sewage treated per acre per 24 hours, 121,600.]	711,476 (average number)	78,327 (average number)	Varied from 100 to 10,000 per c.c. At least 1,000 would be a fair estimate of the average number.	A fair estimate of the average number would be at least 10, but less than 100, per c.c.

Table B—*continued.*

Sewage Farm.	Total Number of Bacteria per c.c.		Number of B. coli per c.c.	Number o spores of B. enteritidis sporogenes (Klein's "enteritidis change" in milk cultur--) per c c
	Gelatine at 20°C.	Agar at 37°C.		
Beddington effluents - - [Domestic sewage; gravelly loam; screening surface irrigation and a little filtration; gallons of sewage treated per acre per 24 hours, 57,100.]	1,413,200 (average number, exclusive of the 1st and 2nd field effluents and the experimental effluents)	112,240	The final effluents usually contained from 100 to 10,000 per c.c. At least 1,000 in 1 c.c. on the average.	A fair estimate of the average number in the final effluents would be at least 10, but less than 100, per c.c.
	2,972,509 (average number, inclusive of all the effluents)	321,600		
Leicester effluents - - - [Mixed sewage; stiff, clayey soil; screening, settling tanks and surface irrigation and filtration combined; gallons of sewage treated per acre per 24 hours, 21,500.]	532,777 (average number, excluding the experimental and 1st field effluents)	70,500	Varied usually from 100 to 1,000 per c.c. At least 1,000 in 1 c.c. on the average.	Varied from 1 to 1,000 per c.c. At least 10, but less than 100, in 1 c.c. would certainly not be an over-estimate of the average number.
	701,363 (average number, excluding the experimental effluents, but including the 1st field effluents)	133,954		
	2,814,555 (average number, inclusive of all the effluents)	260,550		
South Norwood effluents - [Domestic sewage; clay soil; screening, settling tanks and surface irrigation; gallons of sewage treated per acre per 24 hours, 12,000.]	778,322 (average number, exclusive of the 1st and 2nd field and experimental effluents)	35,157	The final effluents varied from 10 to 1,000 per c.c. At least 100 in 1 c.c. would not be an undue estimate of the average number.	Varied from 1 to 100 per c.c. At least 10 in 1 c.c. on the average.
	2,996,207 (average number, inclusive of the 1st and 2nd field, but exclusive of the experimental effluents)	415,872		
	3,658,093 (average number, inclusive of all the effluents)	623,130		
Nottingham effluents - - [Mixed sewage; light, sandy loam; screening (partial) and land filtration; gallons of sewage treated per acre per 24 hours, 23,300.]	The Nottingham effluents are an apparent, rather than real, exception to the general rule that the effluents from land are not in a fit state to be discharged into drinking water streams. This question is fully dealt with in Section VII.			
Rugby effluents - - - - [Mainly domestic sewage; heavy loam; screening, chemical precipitation, settling tanks, surface irrigation and filtration combined; gallons of sewage treated per acre per 24 hours, 42,800.]	637,133 (average number, exclusive of 1st field effluents)	81,526	Varied in the final and general effluents from 10 to 10,000 per c.c. At least 1,000 in 1 c.c. on the average.	Varied usually from 1 to 100 per c.c. At least 10 in 1 c.c. on the average.
	1,682,055 (average number, inclusive of all the effluents)	216,272		

Excluding the Nottingham effluents, it is evident from the above records that it would be under-estimating the facts to state that the effluents from land processes of sewage treatment are apt, on the average, to contain at least from 100 to 1,000 B. coli and at least from 1 to 10 spores of B enteritidis sporogenes per cubic centimetre.

When it is pointed out that in, at all events, some samples of drinking water B. coli may be absent from 100 c.c. and B. enteritidis sporogenes from 500 c.c., there seems, on this basis of comparison, no justification for considering effluents of the above kind in a fit state to be discharged into drinking water streams. Drinking water streams, *per se*, often fail to pass the standards of the biologist; but, even if the stream be assumed to be sterile and of sufficient volume to dilute the effluents from land processes of sewage treatment ten to one hundred times, the mixed liquid would not meet the requirements of the responsible bacteriologist.

On one occasion, a guinea-pig succumbed to pseudo-tuberculosis (B. pseudo-tuberculosis of A. Pfeiffer) consequent to subcutaneous inoculation

with a land effluent, and on more than one occasion B. pyocyaneus obtained from land effluents has proved virulent to guinea-pigs. In some epidemics of diarrhœa the latter microbe has been considered (rightly or wrongly) to have been the infective agent.

In connection with the consideration of non-drinking water streams, it will be pointed out that some of the effluents were in view of their destination, not only satisfactory, but showed a remarkable degree of improvement on bacteriological examination. In the present connexion it is only fair to point out the converse side of the question, namely, that some of the effluents, irrespective of their destination, were so unsatisfactory as to be from the biological point of view hardly (if at all) more safe in their possible relation to disease than "untreated" sewage. It is advisable, in my opinion, to emphasize the *impure* character of the worst land effluents from the epidemiological point of view and in relation to drinking water streams, and to lay stress on the *favourable* character of the best effluents from the practical point of view in connexion with non-drinking water streams, and in illustration of the ability of land, if it is not overworked, adequately to purify sewage.

Before leaving the side of the general question of the land treatment of sewage which chiefly concerns the biologist and epidemiologist, three important questions remain to be considered :—

(1) *What are the biological qualities of the soil on sewage farms?*

(2) *What is the ultimate fate of sewage microbes sown broadcast on soil?*

(3) *Are the effluents from farms rich in microbes peculiar to (in the sense of being specially abundant in) soil, or do they contain in preponderating number microbes of excremental origin?*

The attempt to answer the first two of these questions would have involved a prolonged and difficult research, and it was not practicable, in conjunction with the routine work for the Commission, to undertake such research.

I have, however, in my past research work for the Local Government Board, devoted a considerable amount of time and labour to these questions. It is impossible to describe adequately in a few sentences the results of several years' work, but the following is a brief abstract of some of the chief points of interest :—

(1) In the first place it may be said that the soil of sewage farms, and in general sewage polluted soils, contain streptococci, B. coli, and B. enteritidis sporogenes in great abundance. These undesirable microbes are absent, or relatively absent, from virgin soils. In cultivated soils, much naturally depends on the nature of the treatment or the kind of "dressing" which has been applied to the soil and the time which has elapsed since the soil was last "treated". The spores of B. enteritidis sporogenes tend to remain as evidence of past pollution for a long period; but B. coli and, in my experience, more particularly streptococci (some strains, at all events), when present in any abundance, point to contamination of *recent* and therefore specially objectionable kind.

According as the manuring is recent or remote, and in accordance too with the nature of the fertilising "treatment" and the amount of "dressing" applied to the soil, the bacteriological result will be found to vary. But cultivated soils, in comparison with virgin soils at all events, are apt to be rich in microbes of all sorts, and rich also, not infrequently, in bacteria of excremental origin.

But it must not be concluded because microbes indubitably of intestinal outcome are present in great abundance in sewage polluted soils, that the bacteria characteristic of soil are necessarily, in the struggle for existence, crowded out by the sewage bacteria. In my experience, the soil microbes are not only present but, if the supply of sewage microbes be discontinued, contend with and gradually oust such of the non-sporing bacteria of excremental origin as may be judged to be of adventitious, *i.e.*, non-saprophytic, sort.

This leads me to the second question under consideration, namely, what is the ultimate fate of sewage microbes when sown broadcast on soil.

(2) So complex a problem as the above cannot be readily solved. But it would seem to be the case that, given a cessation of the sewage inoculation process of the land, the streptococci (other than those of peculiar sort) disappear (relatively, if not actually) from the soil somewhat rapidly. So, too, is decline in the number of B. coli very apparent, although the persistence of certain strains of B. coli for weeks or even months is also indicated as the result of my experiments. Many of these coli-like microbes are apt to give a feebly positive, or even negative response to tests, which when brought to bear on the coli of recent intestinal outcome provoke a strongly positive result. The question which remains undetermined is whether these coli-like microbes constitute a race or class of their own, or are micro-organisms which have lost some of their original properties during their sojourn in the soil.

The spores of B. enteritidis sporogenes usually persist for long periods in sewage-treated soil. Such diminution of them as has been observed in its superficial layers may be referred to the spores having been washed into the deeper layers of soil or to the gradual dissolution even of spores; or, possibly, to the spores passing into the vegetative phase of existence, thus becoming more susceptible to the action of deleterious bactericidal influences of one and another sort. Dr. Lorrain Smith favours the view that the infusoria may utilise bacteria as food.

(3) As regards the last question, namely, the proportion of sewage-bacteria to soil-bacteria present in the effluents, in various reports to the Local Government Board I have shown that soil and the "washings" of soil are apt to be characterised bacteriologically by the presence of enormous numbers (both actually and relatively) of the spores of bacteria and by the presence, usually in great abundance among other soil-bacteria, of B. mycoides, the *granular bacillus* of soil, and the *Bismarck brown cladothrix* of soil. A careful and prolonged comparison with these previously accumulated data obtained from the examination of numerous samples of the effluents from the sewage farms has convinced me that the effluents from land processes of sewage treatment exhibit not only the *characteristic bacterial flora of sewage, but are relatively free from soil microbes.*

Occasionally, B. mycoides was met with in the cultivations of land effluent, but so rarely as to be hardly worthy of mention. At the same time, it is to be noted that the term "relatively free" not "actually free" has been employed, because it might well be the case that in the high dilutions used (and, indeed, necessary for working purposes), the soil microbes might be absent, and yet be present sometimes in the lower dilutions.

The question next in importance to be considered is as follows :—

II. *Can the treatment of sewage on land so alter the qualities of sewage as to admit of the discharge of the effluents into non-drinking water streams?*

My reasons for considering—in the case of effluents discharging into non-drinking water streams—the bacteriological secondary in value (in general, although not in particular* cases) to the chemical examination have been fully stated in the introduction to this report. Nevertheless, from this secondary point of view, bacteriological analyses and standards are of considerable importance.

It is difficult, for example, to credit that an effluent teeming with putrefactive microbes is a liquid wherein the objectionable organic pabulum of excremental origin has been completely resolved into harmless inorganic substances. As a matter of fact, however, it has been found generally and broadly speaking that decline in the amount of organic matter is, in sewage effluents, associated with a corresponding reduction in the number of bacteria. There can, therefore, be no question that in practice the number of bacteria (of all sorts, but particularly those commonly associated with the decomposition of animal organic matter) present in a liquid is a valuable, although necessarily an indirect, measure of its potential putrescibility.

* See my Report on the presence of Anthrax at Yeovil in (1) Septic Tank Liquor; (2) Septic Tank Sludge; (3) Primary Coarse Coke Bed; (4) Secondary Fine Coke Bed; (5) General Effluent from Final Catchpit of a Hide Factory; (6) Mud of River Yeo, and (7) Mud of Yeo Brook. (Second Report of Royal Commission on Sewage Disposal, 1902, Cd. 1178.) Further, where there is danger of contamination of shell-fish layings the bacteriological is obviously of greater importance than the chemical examination.

The tests employed in the bacteriological examination of sewage and sewage effluents, the interpretation to be placed on the results obtained by the use of these tests and the standards provisionally suggested are matters which have been so fully considered in the past that it is not necessary to repeat here previous statements and inferences.

In the first place, it is to be noted that of the eight sewage farms kept under special observation none, with the sole and striking exception of Nottingham, yielded average effluents of an *entirely satisfactory* character.

In illustration of this, it may be pointed out that the average number of bacteria (agar at 37°C.) per c.c. in the final effluents derived from Aldershot, Altrincham, Cambridge, Beddington, Leicester, South Norwood and Rugby sewage farms was 37,308, 7,275, 78,327, 112,240, 70,500, 35,157, and 81,526 respectively.

Nevertheless, the results were, in nearly all cases and in relation to all the tests employed, so far satisfactory as to give rise to the belief that land, although of not altogether suitable sort, if it is not greatly overworked, can purify sewage to a reasonable extent.

Secondly, although percentages are apt to be misleading, it may be stated that the percentage improvement in the effluents, as compared with the crude sewage, was in nearly all cases very striking.

Thus, as regards Aldershot, Altrincham, Cambridge, Beddington, Leicester, South Norwood, and Rugby sewage farms the percentage improvement, as judged by the reduction in the number of bacteria (agar at 37°C.), was 99, 99, 95, 97, 95, 99 and 97, respectively.

Thirdly, it may be pointed out that a significant feature of the analyses was the unequal character of the effluents. In considering the subject from the point of view of possible danger to health, and in relation to the discharge of effluents into drinking water streams, stress was laid on the grossly impure character of a proportion of the effluents. So now attention must be directed to the fact that many of the effluents were not only satisfactory, but, considering their origin, remarkably pure bacteriologically. Thus, the number of microbes (agar at 37° C.) per c.c. in the best (on the basis of this test) effluent derived from Aldershot, Altrincham, Cambridge, Beddington, Leicester, South Norwood, and Rugby sewage farms, was 196, 930, 1,080, 900, 300, 980, and 900, respectively.

Lastly, a brief summary of the chief results obtained from the bacteriological examination of sewage and effluents derived from the above seven sewage farms may here with advantage be recorded, together with notes as regards the character of the sewage, the nature of the soil, the method of treatment, and the gallons of sewage treated per acre per 24 hours.

SUMMARY OF BACTERIOLOGICAL RESULTS.

I. *Aldershot Camp Sewage Farm Effluents.*

[Domestic sewage; sandy soil; screening, settling tanks, and land filtration; gallons of sewage treated per acre per 24 hours, 25,000.]

Total number of bacteria (gelatine at 20° C.).—The average number of microbes in the old land effluents was 183,266 per c.c. This number is in excess of the standard of less than 100,000 in 1 c.c. The reduction in the number of bacteria as compared with the sewage was 99 per cent.

Total number of bacteria (agar at 37° C.).—The average number of microbes in the old land effluents was 37,308 per c.c. This number is in excess of the standard of less than 10,000 in 1 c.c. The reduction in the number of bacteria as compared with the sewage was 99 per cent.

B. coli.—A fair estimate of the average number in the old land effluents is at least 1,000, but less than 10,000 per c.c. The provisional standard is less than 1,000 in 1 c.c. The effluents were, on the average about 100 times purer than the sewage.

B. enteritidis sporogenes (Klein's "enteritidis change" in anaerobic milk cultures).—A fair estimate of the average number in the old land effluents is at least 10, but less than 100 per c.c. (+ ·1 c.c., – ·01 c.c.). The provisional

standard is less than 10 in 1 c.c. (– ·1 c.c.) The effluents were, on the average, about 100 times purer than the sewage on the basis of this test.

"Gas" test ("gas" in gelatine "shake" cultures, 24 hours at 20° C.).—The general results may be expressed as follows:—From + 1, – ·1 c.c., to + ·1, – ·01 c.c., but on the average + 1, – ·1 c.c. Provisional standard, negative result with ·1 c.c. The effluents were, on the average, about 1,000 times purer than the sewage on the basis of this test.*

Neutral red broth test.—A fair estimate of the average result is + ·001, – ·0001 c.c. Provisional standard, negative result with ·001 c.c. The effluents were, on the average, about 100 times purer than the sewage on the basis of this test. §

II. *Altrincham Sewage Farm Effluents.*

[Domestic sewage; peaty and sandy soil; settling tank, and land filtration; gallons of sewage treated per acre per 24 hours, 46,000.]

Total number of bacteria (gelatine at 20° C.).—The average number of microbes in the effluents was 363,400 per c.c. This number is in excess of the standard of less than 100,000 in 1 c.c. The reduction in the number of bacteria as compared with the sewage was 97 per cent.

Total number of bacteria (agar at 37° C.).—The average number of microbes in the effluents was 7,275 per c.c. This number easily passes the standard of less than 10,000 in 1 c.c. The reduction in the number of bacteria as compared with the sewage was 99 per cent.

B. coli.—A fair estimate of the average number is at least 100, but less than 1,000 per c.c. The provisional standard is less than 1,000 per c.c. The effluents were, on the average, about 1,000 times purer than a normal sewage. Altrincham sewage, however, was in some respects a weak sewage.

B. enteritidis sporogenes (Klein's "enteritidis change" in anaerobic milk cultures).—A fair estimate of the average number is at least 1, but less than 10 in 1 c.c. (+ 1, 1 c.c). The provisional standard is less than 10 in 1 c.c. (+ 1, - ·1 c.c). The effluents were, on the average, about 1,000 times purer than a normal sewage.

"Gas" test ("gas" in gelatine "shake" cultures, 24 hours at 20° C.).—A fair estimate of the average result is + 1, – ·1 c.c. Provisional standard, negative result ·1 c.c. The effluents, on the average, were about 100 times purer than the sewage (*see* footnote under Aldershot Camp).

Neutral red broth test.—A fair estimate of the average result is + ·01, – ·001 c.c. Provisional standard, negative result with ·001 c.c. The effluents were, on the average, at least 100 times purer than the sewage (*see* footnote under Aldershot Camp).

III. *Cambridge Sewage Farm Effluents.*

[Mainly domestic sewage; sandy loam; screening, settling tank, and land filtration; gallons of sewage treated per acre per 24 hours, 121,600.]

Total number of bacteria (gelatine at 20° C.).—The average number of bacteria in the finally treated effluents was 711,476 per c.c. This number is considerably in excess of the standard of less than 100,000 in 1 c.c. The reduction in the number of bacteria as compared with the sewage was 94 per cent.

---

* As regards this test the observations are made after 24 hours at 20° C., because, by so limiting the incubation period troublesome dilutions are avoided, an effluent may be passed (on the basis of this test) if it gives a negative result with 0·1 c.c. But the results, of course, do not give the absolute but only the relative number of gas-forming bacteria present. If the period of incubation is lengthened the standard to be adopted must be modified accordingly. At present, the plan is followed of taking records after 24, 48, and 72 hours' incubation at 20° C.

§ Generally speaking, the above results might almost be stated as at least 1,000 but not 10,000 coli-like bacteria per c.c. (+ ·001 c.c., – ·0001 c.c.). That is, when dealing with domestic sewage and sewage effluents. But, strictly speaking, the method employed here of recording the results is the only absolutely exact method.

Total number of bacteria (agar at 37° C.).—The average number of bacteria in the finally treated effluents was 78,327 per c.c. This number is considerably in excess of the standard of less than 10,000 in 1 c.c. The reduction in the number of bacteria as compared with the sewage was 94 per cent.

B. coli.—A fair estimate of the average number is at least 1,000, but less than 10,000 in 1 c.c. The provisional standard is less than 1,000 in 1 c.c. The effluents were, on the average, about 100 times purer than the sewage.

B. enteritidis sporogenes (Klein's "enteritidis change" in anaerobic milk cultures).—A fair estimate of the average number in the effluents is at least 10, but less than 100 per c.c. (+ ·1 c.c., − ·01 c.c.). The provisional standard is less than 10 in 1 c.c. The effluents were, on the average, about 100 times purer than ordinary sewage, and at least 10 times purer than Cambridge sewage.

"Gas" test ("gas" in gelatine "shake" cultures, 24 hours at 20° C.).—A fair estimate of the average result is + ·1, − ·01 c.c. Provisional standard, negative result ·1 c.c. The effluents were, on the average, about 100 times purer than ordinary sewage, and at least 10 times purer than Cambridge sewage (*see* footnote under Aldershot Camp).

IV. *Beddington (Croydon) Sewage Farm Effluents.*

[Domestic sewage; gravelly loam; screening, surface irrigation, and a little filtration; gallons of sewage treated per acre per 24 hours, 57,100.]

Total number of bacteria (gelatine at 20° C.).—The average number of bacteria in the finally treated effluents was 1,413,200 per c.c. This number is greatly in excess of the standard of less than 100,000 in 1 c.c. The reduction in the number of bacteria as compared with the sewage was 95 per cent.

Total number of bacteria (agar at 37° C.).—The average number of microbes in the effluents was 112,000 per c.c. This number is considerably in excess of the standard of less than 10,000 in 1 c.c. The reduction in the number of bacteria as compared with the sewage was 97 per cent.

B. coli.—A fair estimate of the average number is at least 1,000, but less than 10,000 per c.c. The provisional standard is less than 1,000 in 1 c.c. The effluents were, on the average, about 100 times purer than the sewage.

B. enteritidis sporogenes (Klein's "enteritidis change" in anaerobic milk cultures).—A fair estimate of the average number in the effluents is at least 10, but less than 100 per c.c. (+ ·1 c.c., − ·01 c.c.). The provisional standard is less than 10 in 1 c.c. (− ·1 c.c.). The effluents were, on the average, about 100 times purer than the sewage.

"Gas" test ("gas" in gelatine "shake" cultures, 24 hours at 20° C.).—A fair estimate of the average result is + ·1, − ·01 c.c. Provisional standard, negative result ·1 c.c. The effluents were, on the average, about 100 times purer than the sewage (*see* footnote under Aldershot Camp).

Neutral red broth test.—A fair estimate of the average result is + ·001, − ·0001 c.c. Provisional standard, negative result with ·001 c.c. The effluents were, on the average, about 100 times purer than the sewage (*see* footnote under Aldershot Camp).

V. *Leicester Sewage Farm Effluents.*

[Mixed sewage; stiff clayey soil; screening, settling tanks, surface irrigation and filtration combined; gallons of sewage treated per acre per 24 hours, 21,500.]

Total number of bacteria (gelatine at 20° C.).—The average number of bacteria in the finally treated effluents was 532,777 per c.c. This number is in excess of the standard of less than 100,000 in 1 c.c. The reduction in the number of bacteria as compared with the sewage was 95 per cent.

Total number of bacteria (*agar at* 37° *C.*).—The average number of bacteria in the finally treated effluents was 70,500 per c.c. This number is in excess of the standard of less than 10,000 in 1 c.c. The reduction in the number of bacteria as compared with the sewage was 95 per cent.

B. coli.—A fair estimate of the average number is at least 1,000, but less than 10,000 in 1 c.c. The provisional standard is less than 1,000 in 1 c.c. The effluents were, on the average, about 100 times purer than the sewage.

B. enteritidis sporogenes (*Klein's "enteritidis change" in anaerobic milk cultures*).—Exceptional cases apart, a fair estimate of the average number is at least 10, but less than 100 per c.c. (+ ·1 c.c., – ·01 c.c.). The provisional standard is less than 10 in 1 c.c. (– ·1 c.c.). The effluents were, on the average, about 100 times purer than the sewage.

"Gas" test (*"gas" in gelatine "shake" cultures,* 24 *hours at* 20° *C.*).—Exceptional cases apart, a fair estimate of the average result is + ·1, – ·01 c.c. Provisional standard, negative result ·1 c.c. The effluents were, on the average, about 100 times purer than the sewage (*see* footnote under Aldershot Camp).

Neutral red broth test.—Exceptional cases apart, a fair estimate of the average result is ·001, – ·0001 c.c. Provisional standard, negative result with ·001 c.c The effluents were, on the average, about 100 times purer than the sewage (*see* footnote under Aldershot Camp).

VI. *South Norwood Sewage Farm Effluents.*

[Domestic sewage; clay soil; screening, settling tanks, and surface irrigation; gallons of sewage treated per acre per 24 hours, 12,000.]

Total number of bacteria (*gelatine at* 20°*C.*).—The average number of bacteria in the finally treated effluents was 778,322 per c.c. This number is considerably in excess of the standard of less than 100,000 in 1 c.c. The reduction in the number of bacteria as compared with the sewage was 98 per cent.

Total number of bacteria (*agar at* 37°*C.*).—The average number of bacteria in the finally treated effluents was 35,157 per c.c. This number is in excess of the standard of less than 10,000 in 1 c.c. The reduction in the number of bacteria as compared with the sewage was 99 per cent.

B. coli.—A fair estimate of the average number in the finally treated effluents is at least 100, but less than 1,000 in 1 c.c. The provisional standard is less than 1,000 in 1 c.c. The effluents were, on the average, about 1,000 times purer than the sewage.

B. enteritidis sporogenes (*Klein's "enteritidis change" in anaerobic milk cultures*).—A fair estimate of the average number in the finally treated effluents is at least 10, but less than 100 per c.c. (+ ·1 c.c., – ·01 c.c.). The provisional standard is less than 10 in 1 c.c. (– ·1 c.c.). The effluents were, on the average, about 100 times purer than ordinary sewage, and from 10 to 100 times purer than South Norwood sewage.

"Gas" test (*"gas" in gelatine "shake" cultures,* 24 *hours at* 20°*C.*).—A fair estimate of the average result is + ·1, – ·01 c.c. Provisional standard, negative result with ·1 c.c. The effluents were, on the average, about 100 times purer than the sewage (*see* footnote under Aldershot Camp).

VII. *Nottingham Sewage Farm.*

[Mixed sewage; light, sandy loam; land filtration; gallons of sewage treated per acre per 24 hours, 23,300.]

The effluents from Nottingham were remarkably good, and, with a few exceptions (chiefly from overworked land), easily "passed" the standards set up for the various tests employed. The effluents being quite exceptional in character, can hardly be fairly dealt with in this summary, and reference must be made to Section VII. for details. Nevertheless, it may be noted that the number of bacteria was frequently less than 1,000; of B. coli less than 10; and of B. enteritidis sporogenes less than one per c.c. The "gas" test usually yielded a negative result with 1 c.c. The neutral red broth test usually gave a positive result with ·1 c.c.; and a negative result with ·01 c.c.

VIII. *Rugby Sewage Farm Effluents.*

[Mainly domestic sewage; heavy loam; screening, chemical precipitation, settling tanks, and surface irrigation and filtration combined; gallons of sewage treated per acre per 24 hours, 42,800.]

Total number of bacteria (*gelatine at* 20° *C.*).—The average number of bacteria in the finally treated effluent was 637,133 per c.c. This number is in excess of the standard of less than 100,000 in 1 c.c. The reduction in the number of bacteria as compared with the sewage was 97 per cent.

Total number of bacteria (*agar at* 37° *C.*).—The average number of bacteria in the finally treated effluents was 81,526 per c.c. This number is considerably in excess of the standard of less than 10,000 in 1 c.c. The reduction in the number of bacteria as compared with the sewage was 97 per cent.

B. coli.—A fair estimate of the average number is at least 1,000, but less than 10,000 in 1 c.c. The provisional standard is less than 1,000 in 1 c.c. The effluents were, on the average, about 100 times purer than the sewage.

B. enteritidis sporogenes (*Klein's "enteritidis change" in anaerobic milk cultures*).—A fair estimate of the average number is at least 10, but less than 100 per c.c. (+ ·1 c.c., − ·01 c.c.). The provisional standard is less than 10 in 1 c.c. − ·1 c.c.). The effluents were, on the average, about 100 times purer than the sewage.

"Gas" test (*"gas" in gelatine "shake" cultures*, 24 *hours at* 20° *C.*).—A fair estimate of the average result is + ·1, − ·01 c.c. Provisional standard, negative result ·1 c.c. The effluents were, on the average, about 100 times purer than the sewage (*see* footnote under Aldershot Camp).

Neutral red broth test.—A fair estimate of the average result is + ·01, − ·001 c.c. Provisional standard, negative result with ·001 c.c. Only a few effluents were examined, but those tested were about 1,000 times purer than sewage (*see* footnote under Aldershot Camp).

The following table is an abstract of the foregoing results :—

Sewage Farm Effluents.	Average number of bacteria (gelatine at 20° C.)	Average number of bacteria (agar at 37° C.)	Average number of B. coli per c.c.	Average number of spores of B. enteritidis sporogenes per c.c.	"Gas" test ("gas" in gelatine "shake" cultures in 24 hours at 20° C.) average result.	Neutral red broth test average result.	Remarks.			Gallons of Sewage treated per acre per 24 hours (dry weather flow divided by the average area irrigated at one time.)
							Sewage.	Soil.	Method of Treatment.	
I. Aldershot Camp	183,266 (99 per cent. reduction)	37,308 (99 per cent. reduction)	At least 1,000, but less than 10,000	At least 10, but less than 100	+ 1 ; − ·1 c.c.	+ ·001 ; − ·0001 c.c.	Domestic	Sandy	Screening, settling tanks and land filtration	25,000 *(8,300)
II. Altrincham	363,400 (97 per cent. reduction)	7,275 (99 per cent. reduction)	At least 100, but less than 1,000	At least 1, but less than 10	+ 1 ; − ·1 c.c.	+ ·01 ; − ·001 c.c.	Domestic	Peaty and sandy	Settling tank and land filtration	46,000 *(23,000)
III. Cambridge	711,476 (94 per cent. reduction)	78,327 (94 per cent. reduction)	At least 1,000, but less than 10,000	At least 10, but less than 100	+ ·1 ; − ·01 c.c.	No record.	Mainly domestic	Sandy loam	Screening, settling tank and land filtration	121,600 *(30,400)
IV. Beddington (Croydon)	1,413,200 (95 per cent. reduction)	112,000 (97 per cent. reduction)	At least 1,000, but less than 10,000	At least 10, but less than 100	+ ·1 ; − ·01 c.c.	+ ·001 ; − ·0001 c.c.	Domestic	Gravelly loam	Screening, surface irrigation and a little filtration	57,100 *(9,500)
V. Leicester	532,777 (95 per cent. reduction)	70,500 (95 per cent. reduction)	At least 1,000, but less than 10,000	At least 10, but less than 100	+ ·1 ; − ·01 c.c.	+ ·001 ; − ·0001 c.c.	Mixed	Stiff clayey soil	Screening, settling tanks, surface irrigation and filtration combined	21,500 *(5,370)
VI. South Norwood	778,322 (98 per cent. reduction)	35,157 (99 per cent. reduction)	At least 100, but less than 1,000	At least 10, but less than 100	+ ·1 ; − ·01 c.c.	No record.	Domestic	Clay soil	Screening, settling tanks, surface irrigation	12,000 *(4,000)
VII. Nottingham	Results very variable, frequently less than 1000.	Results very variable, frequently less than 1000.	Usually less than 10	Usually less than 1	Negative 1 c.c.	+ ·1 ; − ·01 c.c.	Mixed	Light sandy loam	Screening (partial), land filtration	23,300 *(10,750)
VIII. Rugby	637,133 (97 per cent. reduction)	81,526 (97 per cent. reduction)	At least 1,000, but less than 10,000	At least 10, but less than 100	+ ·1 ; − ·01 c.c.	+ ·01 ; − ·001 c.c.	Mainly domestic	Heavy loam	Screening, chemical precipitation, settling tanks and surface irrigation and filtration combined.	42,800 *(8,500)
Sewages †	10 not 100 million	1 not 10 million	About 100,000	100 to 100,000	Usually + ·01 to + ·001 c.c.	Usually + ·00001 c.c.				
Provisional Standards	Less than 100,000 per c.c.	Less than 10,000 per c.c.	Less than 1,000 per c.c.	Less than 10 per c.c.	Negative result ·1 c.c.	Negative result ·001 c.c.	Provisional standards.			

* The figures in brackets in the last column refer to the gallons of sewage treated per acre per 24 hours on the assumption that each acre of the irrigable area is under sewage all the time (dry weather flow divided by the total irrigable area). The importance of this distinction is clearly set forth in the General Report (Part I.).

It must be remembered that averages are sometimes misleading and that a few really bad effluents may so alter the average figures as to make the effluents from a sewage farm appear worse than was perhaps actually the case. The above summary should be read in relation to the detailed statements made in Sections I. to VIII.

† The above broad statement applies to the sewages from all the eight sewage farms.

From the foregoing summary it is evident that, though the effluents did not on the average pass the standards set up for the various tests, they all showed a high percentage degree of purification. In most cases the farms were treating too much sewage per acre either actually (e.g., Cambridge, land filtration); or relatively to the method of treatment (e.g., Beddington, surface irrigation with some filtration); or both the method of treatment and the nature of the soil (e.g., Rugby, surface irrigation and filtration combined). Given a fair proportion between (1) the volume and character of the sewage to be "treated" and (2) the total irrigable area and the average area irrigated at one time of the farm, and the suitability of the soil for purification purposes, there can be little doubt that effluents from land processes of sewage treatment could be produced which would more than pass the suggested standards (primary standards). If the standards were made ten times more lenient, a concession not perhaps unduly great from the bacteriological point of view in connection with *non-drinking water streams*, all the effluents would then pass the modified or secondary standards with the exception of Beddington (total number of microbes present). Nevertheless, when it is remembered how easily the best effluents from each sewage farm "passed"; how near, comparatively speaking, the average effluents were to "passing"; and how large was the volume of sewage being treated (either actually or relatively to the suitability of the soil for sewage purification purposes), it cannot well be contended that the primary standards provisionally suggested for working purposes are of a drastic and wholly impracticable nature.* They would, however, admittedly press with possibly undue severity on most artificial (bacteria bed) processes of sewage purification. These artificial (bacteria bed) processes, in the opinion of some persons, aim too much at treating as large a volume of sewage per unit of area as will yield effluents *barely* passing existing standards of purity, and too little at so treating sewage as to yield effluents of an indubitably satisfactory character. The question of practicability must needs determine the method and procedure to be adopted as regards artificial processes, but it is well to strive to reach with them a high standard.

The question may be asked: Are effluents resulting from (a) purposely contrived filtration through land immeasurably better from the bacteriological point of view than effluents obtained in the main by (b) surface irrigation? This is a difficult question to answer, for many reasons. Apart from the difference in the kind of treatment ((a) filtration as compared with (b) surface irrigation), other factors, the effect of which cannot be weighed or measured, varied to a considerable extent. For example, the volume and character of the sewage being treated per acre, the presence or absence of crops, the drainage arrangements, the antecedent treatment,† the management of the farm, the question of storm water, and other variable factors.

There was certainly no comparison between the Nottingham land filtration effluents and the effluents from any of the other sewage farms that were examined‡. Excluding Nottingham, the land filtration effluents from Aldershot, Cambridge, and Altrincham (land filtration proper) were not conspicuously better than those obtained from Beddington (surface irrigation and a little filtration), Leicester (surface irrigation and filtration combined), South Norwood (surface irrigation) and Rugby (surface irrigation and filtration combined). Cambridge (sandy loam), however, was treating at one time a very large amount of sewage (121,600 gallons per acre per 24 hours), and the nature of the soil on Aldershot (sand) and Altrincham (peaty and sandy) sewage farms was not of the kind best suited for treating large volumes of sewage by land filtration methods. On the other hand, Beddington (gravelly loam) and Rugby (heavy loam) farms were treating large volumes of sewage per acre (57,100 and 42,800 gallons per acre of the working irrigable area per 24 hours, respectively).§

* If the existing condition of our rivers be deemed unsatisfactory, it can serve no good purpose to seek to justify the choice of a low standard of purity in connection with sewage effluents. On the contrary, a certain stringency tempered with an adequate conception of what is practicable would seem to be desirable.

† For example, screening, sedimentation and the like.

‡ For details as to these land processes *see* the preceding tables.

§ It needs to be remembered that the various sewage farms were utilising on the average and at one time widely different proportions of their total irrigable area (*see* preceding tables).

Doubtless a land filtration effluent from a deep light loamy soil would be incomparably better than a surface irrigation effluent from an impervious heavy clay soil, both treating on equal areas sewage of the same volume and character. But it is probable that by over-working even a light loamy soil a land filtration effluent may before long be brought to the same condition as a surface irrigation effluent from a heavy clay soil less heavily sewaged. The experience at Nottingham favours this view. It is at all events satisfactory to find that surface irrigation effluents may reach reasonable standards of purity.

The variable factors above alluded to make it extremely difficult to compare the value of land of different kinds.* It would not, for example, be fair to compare Nottingham (deep light loam) with Rugby (heavy shallower loam), especially since the latter was treating at one time nearly twice as much sewage (42,800 gallons against 23,300) per acre. Conversely, the volume of sewage being treated at one time per acre per 24 hours at Cambridge (121,600 gallons) was ten times greater than that treated at South Norwood (12,000 gallons), the former being a sandy loam overlying gravel and sand, and the latter disintegrated clay resting on London Clay. The results were not widely dissimilar in the two cases, although the South Norwood effluents were on the whole the better, and so it may be conjectured that sandy loam can "treat" much larger volumes of sewage than a clay soil of the class in question. If Leicester (stiff clay) be compared with Nottingham (light loam), both farms treating at one time per acre an approximately equal amount of sewage (21,500 and 23,300 gallons per acre per 24 hours, respectively), it is found that the bacteriological results differed to a conspicuous extent in the two cases, the latter yielding exceptionally good effluents, and the former effluents only moderately good.

Further, Beddington (gravelly loam) yielded on the whole worse results than Cambridge (sandy loam), although treating less than one-half the amount of sewage per acre (57,100 and 121,600 gallons per acre of the "working" irrigable area per 24 hours, respectively). Perhaps the most useful lesson to be learnt from the results is that land if only in sufficient amount, even of unsuitable quality for sewage purification purposes, can yield moderately good effluents.

In practice, land, if suitable, is apt to be called upon to treat an even larger proportion of sewage than its degree of suitability would warrant; and, if unsuitable, it is "dosed" with sewage to a smaller extent actually, but relatively to its unsuitable character to an equal extent, than suitable land. For this reason probably the effluents from different kinds of land do not show the wide disparity of results which otherwise might be anticipated.

The practical side of the question is dealt with in the General Report (Part I.).

The third question which merits attention is as follows:—

III. *Is the treatment of sewage on land to be preferred to its treatment by artificial processes, e.g., contact beds, continuous filters, etc.?*

The artificial processes are still under investigation, and it is perhaps not desirable at present to express any definite opinion on this question.

The artificial processes are still in the experimental stage, and for the most part they have been worked rather with a view to treating as large an amount of sewage as possible compatible with producing a non-putrescible effluent than with a view to producing an effluent of the greatest purity.

Worked in the way which has been usually adopted, the effluents from these processes as judged bacteriologically are not equal to the effluent obtained from land of average suitability. But there seems to be no reason to assume that these effluents might not be brought up to any reasonable standard required, either by working the process at a much slower rate, by subsequently passing them through some special filter, or chemically treating them.

* Of course, in point of fact, (a) "filtration" and suitable land and (b) "surface irrigation" and unsuitable land are correlated conditions.

Lastly, the following question requires consideration :—

IV. *What degree of biological modification does the sewage undergo as the result of its treatment on land?*

The question has already been considered in connection with the discharge of sewage effluents into drinking water streams. So far as the actual results are concerned, the effluents show no very appreciable biological modification beyond a reduction in the number of bacteria which they, as sewage, contained. Sometimes, it is true, the spores of B. enteritidis sporogenes were reduced in number to a seemingly less extent than the gas-forming bacteria. But it is a remarkable circumstance not admitting of ready explanation that, both with land and with artificial (bacteria bed) processes of sewage treatment, the spores of bacteria are reduced usually, although not always, to *approximately* the same extent as are the bacteria present in the bacillary form. Dr. Lorrain Smith favours the view that the infusoria may utilise the bacteria as food. Possibly this parallelism is more apparent than real, as the range of the two tests for spores and for bacilli differs so widely as to make comparisons between the tests difficult. Further, there was some evidence, especially in the better class of effluents obtained by land treatment, of a greater proportionate reduction (i.e. as compared with crude sewage) in the number of microbes growing at blood-heat than of those growing at 20° C. Moreover, on several occasions failure was experienced in isolating streptococci from the effluents. Unfortunately, however, the streptococcus test is not an easy one, and is more significant in its positive than in its negative aspects. That is, failure to isolate streptococci need not, unless the experiments are many and prolonged, mean more than their relative absence.

Lastly, of more subtle modifications of the bacteria, such as loss of essential property, nothing can be said, except as conjecture, and this aspect of the question has already been dealt with under Question I.

It must also be remembered that the media and particular processes employed in the investigation might fail to demonstrate biological modifications of the bacteria in cases where such modifications really existed. For example, the mere presence of oxidised nitrogen in an effluent is practical proof of the multiplication of the nitroso and nitro-bacteria. No doubt these are largely retained in the soil ; but it is probable that their number in the effluent is *relatively* greater than in the crude sewage. Some tentative observations made in 1898, and alluded to in my reports to the London County Council, seemed to support this view, and later work for the Commission tended to show that the nitroso-bacteria, at all events, may, under certain circumstances, be *relatively* increased in the effluent from artificial processes of sewage treatment, and present also in great abundance in the "washings" of coke filters which yield good results, as regards nitrification.

In conclusion attention may be directed to certain considerations of a subsidiary sort :—

A. *The impure state of the rivers or brooks into which effluents are being discharged.*

This is a question which must needs have some bearing on the choice of standards.

The effluents from Aldershot Camp, Altrincham, Cambridge, Beddington (Croydon), Leicester, South Norwood, Nottingham, Rugby and Worsley sewage farms discharge severally into the Blackwater River, the Sinderland Brook, the River Cam, the River Wandle, the Anstey Brook (flowing into River Soar), the Chaffinch Beck, the River Trent, the River Avon, and the Parrin Brook.

From a bacteriological point of view, all these rivers or streams are impure—many of them very impure—above the effluent outfalls. The chief results are shown in the following table :—

	Description of the Samples.	Total number of bacteria per c.c.		Number of B. coli (or closely allied forms) per c.c.	Number of spores of B. enteritidis sporogenes (Klein's "enteritidis change" in milk culture) per c.c.	Remarks.
		Gelatine at 20° C.	Agar at 37° C.			
Aldershot Camp	57. Blackwater river water above point of discharge of effluent 27th March, 1900	8,200	500	At least 10 (Indol test + ·1 c.c.)	At least 10	"Gas" test + 1, − ·1 c.c.
Aldershot Camp	326. As above - - - - - 24th July, 1901.	—	—	—	At least 10, but less than 100	Neutral red broth test + ·01, − ·001 c.c. Litmus milk test, acid clot + ·1 c.c. "Gas" test + ·1, − ·01 c.c.
Altrincham	71. Sinderland brook water above effluent outfall 7th May, 1900	53,000	6,700	At least 100 (Indol test + ·01 c.c.)	At least 10, less than 100	"Gas" test + ·1, − ·01 c.c.
Cambridge	222. Cam river water above effluent outfalls 6th February, 1901	38,000	1,400	10, not 100 (Indol test + ·1, − ·01 c.c.)	At least 1, less than 10.	"Gas" test − 1 c.c.
Beddington	45. Wandle river water above effluent outfalls 26th November 1900	72,000	2,680	10, not 100 (Indol + ·1 c.c.)	+10 c.c., −1 c.c.	—
Leicester	133. Anstey brook water above effluent outfalls 3rd December, 1900	540,000	71,000	1, not 10 (Indol + 1 c.c.)	None in 1 c.c.	—
South Norwood	32. Chaffinch brook water above effluent outfalls 30th January, 1900	7,900	1,100	100, not 1,000 (Indol + ·01 c.c.)	+10 c.c., −1 c.c.	—
Nottingham	120. Trent river water above effluent outfalls 6th August, 1900	—	3,300	100, not 1,000 (Indol + ·001 c.c.)	At least 1, but less than 10	—
Rugby	105. Avon river water above effluent outfalls 9th July. 1900	156,000	7,100	At least 100	Negative 10 c.c.	"Gas" test + 1, − ·1 c.c.
Worsley	284. Parrin brook water above effluent outfalls 20th May, 1901	304,000	41,500	100 (Indol test + ·01 c.c.)	At least 1, but less than 10	—

Except in a few cases as regards individual tests, none of these samples would be rejected according to my standards for effluents destined for discharge into non-drinking water streams; but, of course, they all would be regarded as most impure biologically from the point of view of drinking water streams.

As regards the biological quality of the samples of mixed effluent and river water, the report itself must be consulted.

B. *The biological quality of the subsoil water in the neighbourhood of sewage farms.*

As a good deal of subsoil water usually finds its way into the sewers, and may also gain access to the under-drains on the sewage farms, it was considered advisable to examine a few samples of subsoil water in the neighbourhood of sewage farms. The following is a brief summary of the results :—

	Description of the sample.	Total number of bacteria per c.c.		Number of B. coli (or closely allied forms) per c.c.	Number of spores of B. enteritidis sporogenes (Klein's "enteritidis change" in milk culture) per c.c.	Remarks.
		Gelatine at 20° C.	Agar at 37° C.			
Aldershot Camp.	60. Subsoil water. 2nd April, 1900 Pump well near farm.	720	38	None in 1 c.c. (Indol test, + 1 c.c.)	None in 10 c.c.	"Gas" test. Negative result, 1 c.c. Apparently no chance of contamination from the farm.
Altrincham.	78. Subsoil water. 16th May, 1900 Land under irrigation about 150 yds. distant.	1,200	253	None in 1 c.c. (Indol test, + 1 c.c.)	+10, − 1 c.c.	"Gas" test. Negative result, 1 c.c.
Cambridge.	219. Subsoil water. 30th Jan., 1901 Taken from land drain in vicinity of farm.	4,300	230	None in 1 c.c. (Indol test, + 1, − ·1 c.c.)	− 1 c.c.	"Gas" test. Negative result, 1 c.c. Apparently no chance of contamination from the farm.
Leicester.	5. Subsoil water. 15th Nov. 1899 From high portion of farm; sewaged land within 50 yds.	1,320,000	89,000	100, less than 1,000	− 10 c.c.	*Freshly-dug well, results inconclusive.*
Luton.	242. Well water, 20 ft. deep. 19th March, 1901	40,000	410	At least 10 (Indol test, + 1 c.c.)	− 10 c.c.	Below Luton farm; liable to surrounding soil pollution from contents of tub closets used as manure.
	244. As above. 27th March, 1901	800	266	None in 1 c.c. (Indol test, + 1 c.c.)	− 10 c.c.	
	410. As above. 7th Nov. 1902	52,000	2,090	1, not 10 (Indol test, − 1 c.c.)	− 1 c.c.	
Andover.	415. Shallow water. 13th Nov., 1901 Dr. Vivian Poore's experiment.	1,400	280	1, but less than 10 (Indol test, + 1, − ·1 c.c.)	− 1 c.c.	Neutral red broth test, + ·1 c.c. Surrounding land manured with excremental matters.

The results varied considerably, but, excluding the worst samples, were very good. The best samples were, apart from a knowledge of their source, seemingly fit for drinking purposes on the basis of the results obtained. But in judging waters from the point of view of potability, a more elaborate method of analysis (Pasteur filter-brushing method) than was carried out in the present instance is necessary. Two years' work on the chemical and biological qualities of Chichester well water showed that shallow wells sunk in polluted soil and subsoil may show on *searching* bacteriological investigation unequivocal evidence of excremental and therefore potentially dangerous pollution.

C. The biological qualities of samples of (1) *storm water, and* (2) *"street washings."* (Separate system).

1.—As is well known, sewage, when diluted with rain water, is commonly discharged into rivers in the "untreated" condition. For practical reasons it may be impossible to insist on the treatment at outfall works of more than a few times the dry weather flow of sewage. But it should be remembered that sewage diluted even six or more times with pure water would still remain a liquid as potentially dangerous to health as normal crude sewage. The grossly impure character of "storm water" should be borne in mind with the view of enforcing treatment of the whole of it, if this be practicable. If it is found to be impracticable to treat more than

a certain volume, the foul character of the liquid escaping in time of storm into the river in the untreated condition must needs militate against the adoption of standards of purity for "effluents" of too stringent a sort.

During the course of the investigation, we were only able to collect a few samples of storm sewage. But later a fair number of samples have been examined, and the results obtained confirm the truth of the above statements.

2.—As regards "street washings" (separate system), it has been perhaps too readily assumed in the past that the storm-liquid resulting from the adoption of the separate system is relatively unobjectionable. From the bacteriological point of view, this liquid may be grossly and dangerously (potentially speaking) impure.

The following is a brief summary of the chief results :—

	Description of Sample.	Total number of bacteria per c.c.		Number of B. coli (or closely allied forms) per c.c.	Number of spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk culture) per c.c.	Remarks.
		Gelatine at 20° C.	Agar at 37° C.			
Altrincham.	67. Storm water overflow after running for 30 minutes. 29th April, 1900	17,600,000	1,480,000	100,000 (Indol test, + ·00001 c.c.)	At least 100, but less than 1,000	"Gas" test: + ·01, – ·001 c.c. 2 c.c of the sample were injected subcutaneously into a guinea-pig. The animal died on the third day.
	68. Same as above after the overflow had been working 1½ hours	26,100,000	1,640,000	10,000, not 100,000 (Indol test, + ·00001 c.c.)	At least 100, but less than 1,000	"Gas" test: + ·001 – ·0001 c.c. 2 c.c. of the sample were injected subcutaneously into a guinea-pig. The animal died on the third day.
Aldershot Camp.	311. Street "washings" 2nd July, 1901. After 2 days' heavy rainfall	7,500,000	640,000	No record.	At least 10, but less than 100	Neutral red broth test: + ·0001, – ·00001 c.c. Litmus milk test: Acid clot, ·001 c.c. "Gas" test: + ·001, – ·0001 c.c.
	314. As above, but after 3 days' rain (?) slightly contaminated with sewage from the farms	22,800,000	900,000	No record.	At least 100, but less than 1,000	Neutral red broth test: + ·00001 c.c. Litmus milk test: Acid clot, ·0001 c.c. "Gas" test: + ·001, – ·0001 c.c.
South Norwood.	174. Street "washings." 14th Nov., 1900	1,470,000	88,000	At least 10 (Indol test, + ·1 c.c.)	At least 100, but less than 1,000	"Gas" test: + ·1, – ·01 c.c.
	179. As above 21st Nov., 1900	3,840,000	293,000	10,000, not 100,000 (Indol test, + ·00001 c.c.)	At least 10, but less than 100	"Gas" test: + ·01 c.c.
	182. As above, after running 2 hours 28th Nov., 1900	13,700,000	154,000	10,000 (Indol test, + ·0001 c.c.)	At least 100, but less than 1,000	—
	188B. As above, after running 4 hours 1st Dec., 1900	9,900,000	380,000	1,000 (Indol test, + ·001 c.c.)	At least 100, but less than 1,000	"Gas" test: + ·1, – ·01 c.c. A guinea-pig inoculated with 2 c.c. of this sample died on the second day.
Rugby.	96A. "Street washings" 20th June, 1900	15,900,000	94,000	10,000 (Indol test, + ·0001 c.c.)	At least 10, but less than 100	"Gas" test: + 01, – ·001 c.c. 2 c.c. of the sample proved fatal on subcutaneous injection into a guinea-pig.
	231. "Street washings" 4th March, 1901	930,000	12,400	1,000 (Indol test, + ·001 c.c.)	At least 100, but less than 1,000	"Gas" test: – ·1 c.c. Neutral red broth test: + ·01, – ·001 c.c. Litmus milk test: + ·01, – ·001 c.c. A guinea-pig inoculated with 4 c.c. of the sample died on the second day.

It is obvious from the above table that storm overflow and "street washings" liquids may be of a grossly impure character bacteriologically,

and quite unfit for discharge into rivers. Comparing, however, the number of bacteria growing (*a*) in agar at 37° C. and (*b*) gelatine at 20° C. it may be said that the number developing at blood-heat was relatively smaller than is the case in sewage. Many practical considerations may be adduced in favour of the "separate system"; but from the bacteriological point of view, it is impossible to view the above results in any but a serious light. If, for practical reasons, it is necessary to discharge liquids of this kind in the untreated condition into the watercourses, it would seem to be illogical to enforce the adoption of drastic standards of purity in connection with sewage effluents. Nevertheless, excluding for the moment drinking water streams, it must be conceded that an occasional contamination of a watercourse by storm overflow and "street washings" liquids does not stand on the same footing as sustained contamination (effluents from sewage disposal works). It is constantly being urged that as these storm liquids are discharged into flooded rivers, the relative volumes of the storm liquid and river water differ so greatly as to obviate serious contamination of the stream. But river water in storm time is *per se* apt to be impure, often grossly impure, and usually is in no fit condition to dilute additional impurities. A common-sense view of the position is to press for the "treatment" of these liquids if this be practicable, and, if impracticable, to modify our standards of purity as regards sewage effluents. From the biological point of view, and in connection with drinking water streams, the considerations involved are of grave importance.

Summary.

Some diffidence is felt in briefly summarising the foregoing conclusions. It is assumed that what follows in the way of summary will be interpreted in the light of my more detailed and guarded statements, and only accepted as valid subject to the qualifying remarks and reservations that have been previously brought forward.

1.—The treatment of sewage on land (with the apparent rather than real exception of Nottingham) does not so modify the biological qualities of sewage as safely to admit of the direct discharge of the effluents from land processes into drinking water streams.

2.—The bacterial flora of the soil on sewage farms is apt to resemble that of sewage plus in a greater or less degree the microbes characteristic of soil.

3.—With regard to the ultimate fate of sewage microbes sown broadcast on soil, a gradual destruction (relative, if not absolute) of the bacteria of non-sporing and adventitious sort seems to ensue when the application of sewage to the soil is discontinued.

4.—The bacterial flora of effluents from land processes of sewage treatment is characteristic of the bacterial flora of sewage, not of soil.

5.—The average percentage reduction in the total number of bacteria and in the number of B. coli and spores of B. enteritidis sporogenes in the land effluents as compared with the sewage is striking.

6.—The best effluents from the different sewage farms were remarkably modified in the direction of purity, and easily satisfied my suggested bacteriological standards for effluents destined to discharge into non-drinking water streams.

7.—The average biological quality of the effluents from the sewage farms, excluding Nottingham, was not *entirely satisfactory* according to my bacteriological standards (non-drinking water streams). Nevertheless, generally speaking, the effluents came within measurable distance of "passing" the primary and nearly always passed successfully the secondary standards which have been provisionally adopted for working and comparative purposes.

8.—It is extremely difficult for many reasons to compare either (*a*) lan filtration with "surface irrigation" or (*b*) land eminently well suited for

sewage purification processes with land less suitable or of unsuitable sort. Thus as regards (*a*), surface irrigation is commonly combined with some filtration, and in respect of (*b*) suitable land is usually sewaged to a much greater extent than unsuitable land; consequently in the resultant effluent differences are *masked* which otherwise might be very apparent. Of course, in point of fact, (1) filtration and suitable land; and (2) surface irrigation and unsuitable land are usually correlated conditions. There was no comparison between the effluents from Nottingham (light loamy soil, "filtration" effluents) and the effluents from the sewage farms treating sewage in the main by surface irrigation over heavy land. But it is satisfactory to note that surface irrigation effluents from heavy clay soil may, under favourable conditions of working the land, yield reasonably good effluents.

9.—The treatment of sewage on land, as compared with its treatment by artificial processes, is a matter which is still under investigation, and therefore no definite pronouncement can here be made. But, speaking solely from the bacteriological point of view, land (if of suitable sort for sewage purification purposes and properly worked) is, in my opinion, to be preferred to artificial processes as *now conducted.*

10.—The *intrinsic* biological qualities of sewage are not materially modified by land processes of sewage disposal, as judged by the tests employed in this investigation.

11.—Samples of water derived from the rivers or brooks into which "land effluents" are being discharged were usually found *above the effluent outfalls* to be impure (sometimes very impure) on bacteriological examination.

12.—The biological quality of a few samples of the subsoil water in the neighbourhood of sewage farms was determined. The results, as a rule, were satisfactory, but the samples were not examined in the exhaustive manner necessary when the question of potability is involved.

13.—If the examination of "storm overflow liquid" be interpreted in the light of the confirmatory results which were subsequently obtained, it would seem that "storm overflow liquid" is *potentially* as dangerous as undiluted crude sewage.

14.—"Street washings" liquid (separate system) may be a grossly impure liquid from the bacteriological point of view.

APPENDIX I.

Showing as regards (1) *the B. coli and* (2) *indol tests, the results of the bacteriological examination of multiple samples of sewage and of effluents obtained from various sewage farms; together with an analysis of the various coli-like microbes met with during the course of the investigation.*

In this Appendix the results obtained by Dr. Gordon are placed on record. They represent a prolonged and valuable piece of work.

It is to be noted that throughout the whole progress of the inquiry the records, as regards the number of B. coli in the samples of sewage and effluent, are founded *on isolation and study in pure culture of the microbes suspected of being B. coli*, and not on tests which infer the presence of B. coli by a change or changes which when produced in special media are believed to be characteristic of this microbe.

The isolation method, although laborious, is the only one which is not open to criticism, and the results obtained are of such value as more than to compensate for the time and labour involved in their achievement.

The following is a summary of the chief biological characters of the coli-like microbes, isolated from the various samples of sewage and effluents :—

SUMMARY OF COLI-LIKE ORGANISMS.

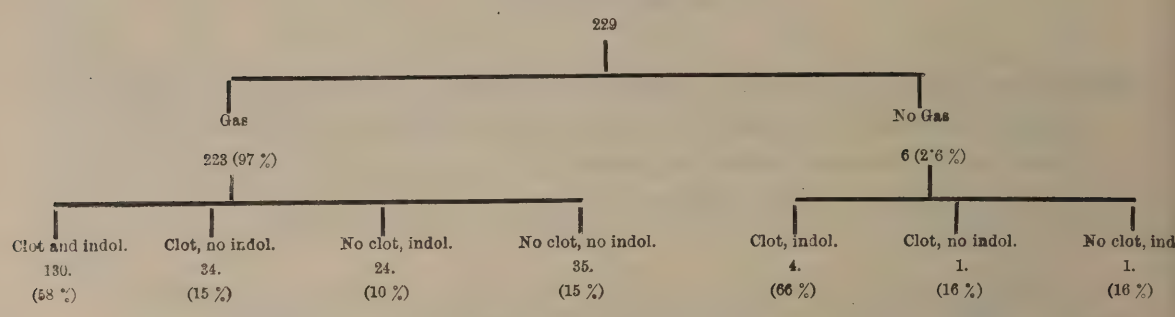
Total number submitted to examination -	229
Total number of these giving all three reactions, viz. :—gas, clot, and indol - -	130 (56 per cent.)

Of the *remaining* 99, the reactions are as follows :—

Gas, no clot, no indol - - - - -	35	(about 35 per cent.)
Gas, clot, no indol - - - - -	34	„ 34 „
Gas, no clot, indol - - - - -	24	„ 24 „
No gas, clot, indol - - - - -	4	„ 4 „
No gas, clot, no indol - - - - -	1	„ 1 „
No gas, no clot, indol - - - - -	1	„ 1 „
	99	

The foregoing results may be expressed as follows:—

Coli-like Organisms.



An alternative summary may be given as follows :—

Of 229 Coli-like Microbes—

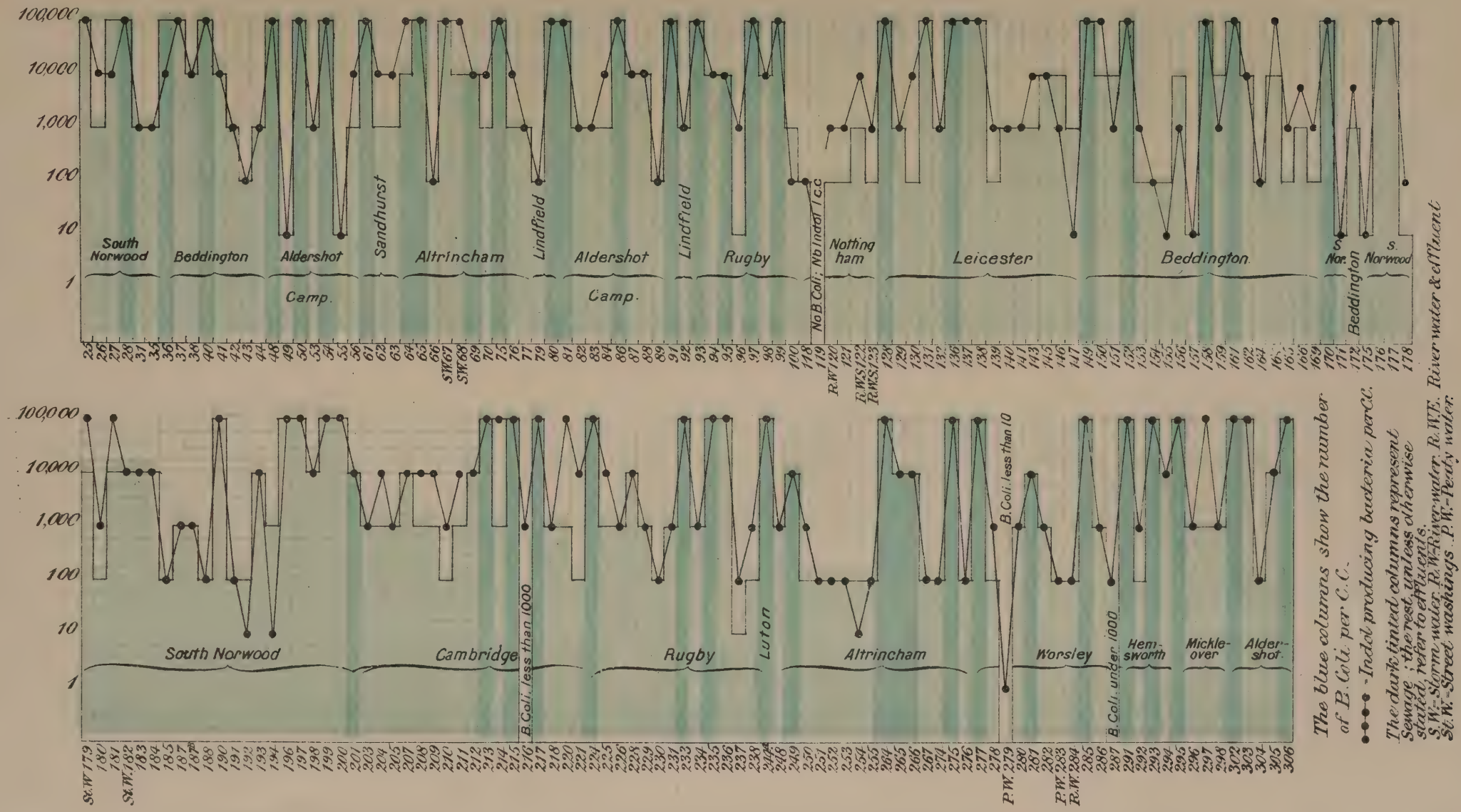
About 97 per cent. produced gas, in gelatine "shake" culture.
,, 2·6 ,, produced no gas, in gelatine "shake" culture.
,, 73 ,, produced clotting, in litmus milk culture.
,, 26 ,, produced no clot, in litmus milk culture.
,, 69 ,, produced indol, in broth culture.
,, 30 ,, produced no indol, in broth culture.
,, 56 ,, gave gas, clot, and indol.
,, 43 ,, failed in one or more respects. Of these only a very small percentage failed as regards gas production, namely, 2·6 per cent. of the total number. As regards clot and indol formation, 26 and 30 per cent., respectively, of the total number failed to give a positive result.

The chief biological characters of the 229 coli-like microbes are given in detail in the accompanying table. These results have already been made the subject of a brief summary.

The appended diagram shows the important relationship between the number of B. coli and of indol-producing bacteria. Although there is obviously a broad parallelism between the two tests, the indol curve, as might be anticipated, tends to run at a somewhat higher level. Apart, however, from this striking agreement, the indol test by itself is a most useful indication of the biological quality of the effluents and, incidentally, of the degree of purification effected by the land treatment.

There are sporing bacteria which can produce indol in broth cultures, but in the case of sewage and effluents the number of such bacteria is very small in comparison with the indol-forming bacilli. The ratio of total number of bacteria to spores of bacteria is a matter which has received much attention in previous reports. Here it is only necessary to call

Diagram showing as regards (1) the B. Coli test and (2) the Indol test the results of the bacteriological examination of Multiple Samples of Sewage and Effluents. The broad parallelism between the B. Coli curve and the Indol curve is striking.



3311 7.02

Weller & Graham Ltd Litho London

attention to the diagram illustrating Appendix VI. (page 212). This diagram shows the results of the bacteriological examination of 25 consecutive samples of sewage and effluent, tested as regards (a) the "ordinary" indol curve, and (b) the "spore" indol curve. It will be noted the "spore" curve never encroaches on the "ordinary" curve, and "runs" at a much lower level.

In conclusion it may, I think, with safety be said that the above results form the most complete record as yet published of the biological qualities of sewage and land effluents, as regards the number and character of the coli-like microbes present in them.

TABLE showing the chief Biological characters of the 229 Coli-like Microbes isolated and studied in

[The figures in thicker type refer to samples of Sewage; the rest, unless otherwise specified, are Land Effluents
W. W. = well water; Sp. W. = sprin

Number of Sample.	"Gas" in Gelatine "Shake" Cultures.	Acid and Clot in Litmus Milk Cultures.	Indol in Broth Cultures.
Leicester:			
1	+	+	+
5	+	–	–
6 R. W. E.	+	–	–
Nottingham:			
10	+	–	–
11	+	+	–
13	+	+	+
16	+	–	–
South Norwood:			
21	–	–	+
22	+	+	–
23	+	–	+
25	+	+	+
26	+	+	+
27	+	–	–
28	+	–	+
29	+	– alk.	–
30	+	+	+
31	+	–	+
32 R. W.	+	–	+
33 R. W. E.	+	–	+
34 R. W. E.	+	–	–
35	+	–	+
Beddington:			
36	+	–	–
37	+	–	–
38	+	–	+
39	+	–	–
40	+	+	+
41	+	–	+
42	+	+	+
43	+	–	+
44	+	+	–
45 R. W.	+	+	+
46 R. W. E.	+	+	+
47 R. W. E.	+	–	–
Aldershot Camp:			
48	+	+	+
49	+	+	+
50	+	+	+
51	+	+	+
52	+	+	+

Number of Sample.	"Gas" in Gelatine "Shake" Cultures.	Acid and Clot in Litmus Milk Cultures.	Indol in Broth Cultures.
Aldershot Camp—*cont.*			
53	+	+	+
54	–	+	+
55	–	+	+
56	+	+	+
57 R. W.	+	+	+
58 R. W. E.	+	+	+
59 R. W. E.	+	+	+
Sandhurst:			
61	+	+	+
62	+	+	+
63	+	+	–
Altrincham:			
64	+	+	+
65	+	+	–
66	+	+	–
67 Stm. W.	+	+	–
68 Stm. W.	+	+	+
69	+	–	–
70	+	–	–
71 R. W.		+	+
72	+	–	–
73 R. W. E.	+	+	–
74 R. W. E.	+	–	+
75	+	+	+
76	+	–	–
77	+	+	–
Lindfield:			
79	+	+	–
80	+	+	–
Aldershot Camp:			
81	+	+	+
82	+	–	+
83	+	+	+
84	+	+	+
86	+	+	+
87	+	–	– alk.
88	+	+	+
89	+	+	+
Lindfield:			
91	+	+	–
92	+	–	+

Number of Sample.	"Gas" in Gelatine "Shake" Cultures.	Acid and Clot in Litmus Milk Cultures.	Indol in Broth Cultures.
Rugby:			
93	+	+	–
94	+	–	+
95	+	–	+
96	+	–	–
96*a* St. W.	+	–	–
97	+	–	+
98	+	–	+
99	+	–	–
100	+	–	+
Nottingham:			
115	+	+	–
118	+	+	–
120 R. W.	+	+	–
21	+	+	+
122 R. W. E.	+	+	–
123 R. W. E.	+	+	+
Leicester:			
124	+	+	–
125	+	+	+
126	+	+	–
127	+	+	–
128	+	+	+
129	+	+	+
130	+	+	+
131	+	+	+
132	+	+	–
133 R. W.	+	+	+
134 R. W. E.	+	+	+
135 R. W. E.	+	+	+
136	+	+	+
137	+	+	+
138	+	+	+
139	+	+	+
140	–	+	–
141	+	–	–
143	+	+	+
145	+	+	+
146	+	+	+
147	+	–	–
Beddington:			
149	+	+	+
150	+	+	+
151	+	–	–

pure culture, from the samples of Sewage and Effluent obtained from various Sewage Farms.

R. W. E. = river water + effluent; R. W. = river water; Stm. W. = storm water; Str. W. = street washings; water; P. W. = peaty water.]

Number of Sample.	"Gas" in Gelatine "Shake" Cultures.	Acid and Clot in Litmus Milk Cultures	Indol in Broth Cultures.
Beddington—*cont.*			
152	+	−	−
153	+	+	+
154	+	− alk.	+
155	−	+	+
156	+	+	+
157	+	+	+
158	+	+	+
159	+	−	−
161	+	+	+
162	+	+	+
164	+	+	+
164*b*	+	+	+
165	+	+	+
166	+	+	−
169	+	−	+
South Norwood :			
170	+	+	+
171	+	+	−
Beddington :			
172	+	+	+
South Norwood :			
174 Str. W.	+	−	−
175	+	+	−
176	+	+	+
177	+	+	+
179 Str. W.	+	−	−
180	+	+	+
181	+	+	+
183	+	+	+
184	+	−	+
185	+	−	−
187	+	+	+
187*b*	+	−	+
188	+	+	+
190	+	+	+
191	+	−	+
192	+	−	+
193	+	+	+
194	+	+	+
195	+	+	+
196	+	+	+
197	+	+	+
198	+	+	+

Number of Sample.	"Gas" in Gelatine "Shake" Cultures.	Acid and Clot in Litmus Milk Cultures.	Indol in Broth Cultures.
South Norwood—*cont.*			
199	+	+	−
200	+	+	−
Cambridge :			
201	+	+	+
203	+	+	+
204	+	+	+
205	+	+	+
207	+	−	−
208	+	+	+
209	+	+	+
210	+	+	+
211	+	−	+
212	+	+	+
213	+	+	−
214	+	+	+
215	+	−	−
217	+	+	+
218	+	+	+
220	+	+	+
221	+	+	+
222 R. W.	+	+	+
223 R. W. E.	+	+	+
Rugby :			
224	+	+	+
225	+	+	+
226	+	+	+
227 W. W.	+	+	+
228	+	+	+
229	+	+	+
230	+	+	+
231 St. W.	+	+	−
233	+	+	+
234	+	+	+
235	+	+	+
236	+	+	+
237	+	+	+
238	+	+	−
339 W. W.	+	+	+
Luton :			
241 Sp. W.	+	+	+
242 W. W.	+	−	−
Exeter :			
Sludge	+	+	+
Effluent	+	+	−

Number of Sample.	"Gas" in Gelatine "Shake" Cultures.	Acid and Clot in Litmus Milk Cultures.	Indol in Broth Cultures.
Luton :			
244*a*	+	+	+
Aldershot :			
246	+	+	+
Altrincham :			
248	+	+	+
249	+	+	+
250	+	+	+
251	+	+	+
252	+	+	−
253	+	+	−
254	+	+	−
255	+	+	+
264	+	+	+
265	+	+	+
266	+	+	+
275	+	+	+
276	+	+	+
Worsley :			
277	+	+	+
278	+	+	+
280	+	+	−
281	+	−	−
283 P. W.	+	−	−
284 R. W.	+	+	+
285	+	−	−
286	+	+	+
290 P. W.	+	+	+
Hemsworth :			
291	+	+	+
293	+	+	+
294	+	−	−
Mickleover :			
295	+	−	−
296	+	+	+
297	+	+	+
298	+	+	+
Aldershot :			
302	+	+	+
303	+	+	+
304	+	+	+
305	+	+	+

APPENDIX II.

Showing as regards the (1) "*Gas*"; (2) *B. enteritidis sporogenes, and* (3) *Neutral-red broth tests, the results of the bacteriological examination of samples of sewage and of effluents obtained from Nottingham, Aldershot Camp, Beddington (Croydon) and Leicester Sewage Farms. Special Comparative series of experiments.*

The results of these experiments have been already dealt with in connection with the description of the above sewage farms. They are here grouped together in one diagram to enable a comparison to be readily drawn between the effluents from the different sewage farms. The soil of the sewage farms, the sewages dealt with, and the methods of treatment may be described very briefly as follows :—

Nottingham.—Light sandy loam ; mixed sewage ; filtration.

Aldershot Camp.—Sand ; domestic sewage ; filtration.

Beddington (Croydon).—Gravelly loam ; domestic sewage ; chiefly surface irrigation.

Leicester.—Stiff clay ; mixed sewage ; chiefly surface irrigation.

The following is a brief summary of the results :—

Gas test:

Nottingham.—All 15 effluents passed the standard -	Standard, negative result $\frac{1}{10}$ c.c.
Aldershot Camp.—10 out of 15 effluents passed the standard - - - - - - - - -	
Beddington (Croydon).—1 out of 15 effluents passed the standard - - - - - - - -	
Leicester.—4 out of 15 effluents* passed the standard -	

It is to be noted, however, that as regards Aldershot Camp, Beddington, and Leicester, 4; no less than 11; and 6 other samples of this series, respectively, came within measurable distance of passing the suggested standard.

B. enteritidis sporogenes test:

Nottingham.—14 out of 15 effluents passed the standard	Standard, negative result $\frac{1}{10}$ c.c.
Aldershot Camp.—3 out of 15 effluents passed the standard - - - - - - - - -	
Beddington (Croydon).—2 out of 15 effluents passed the standard - - - - - - - - -	
Leicester.—5 out of 15 effluents† passed the standard -	

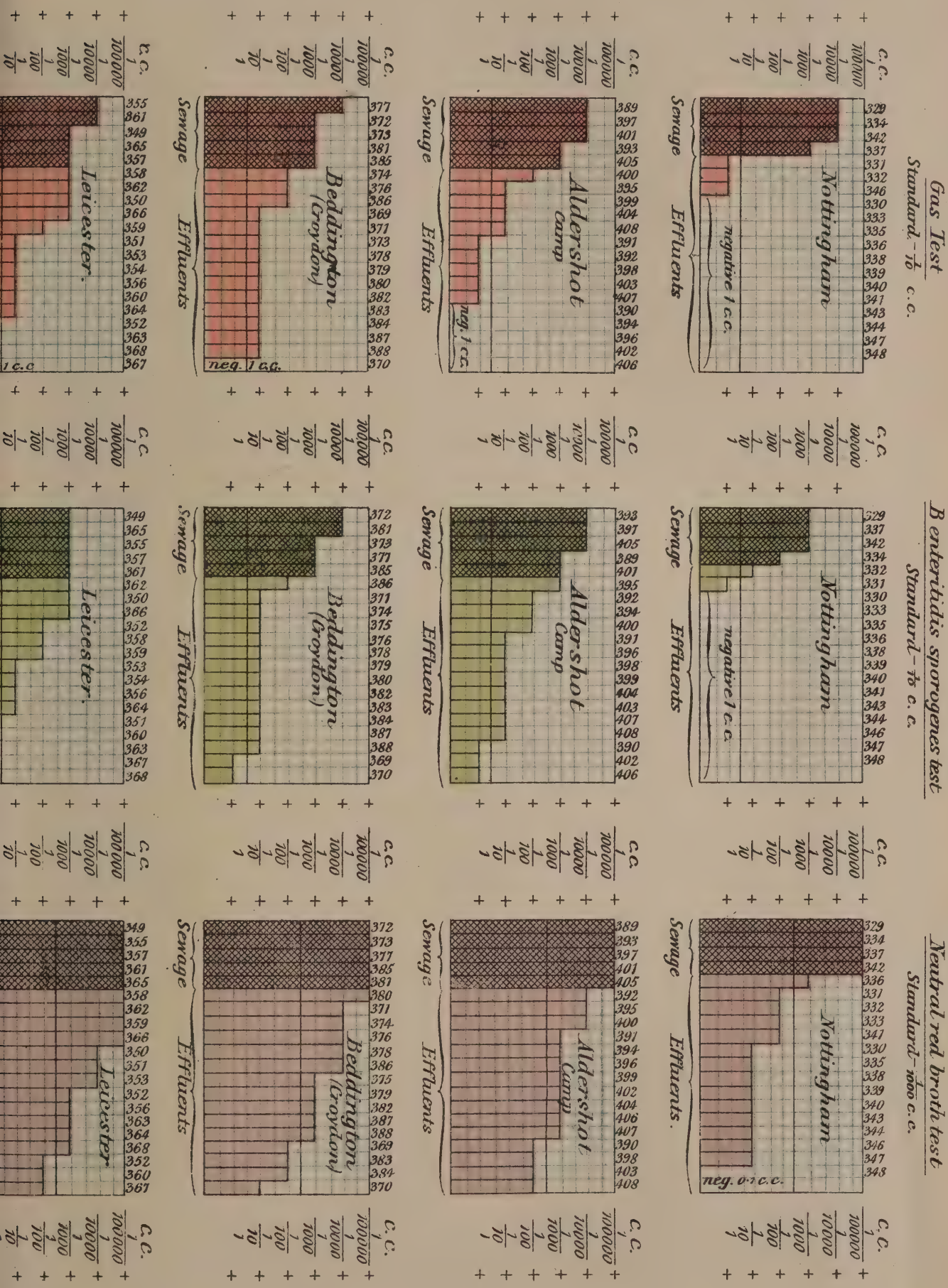
It is to be noted that as regards Aldershot Camp, Beddington, and Leicester, 8; no less than 12; and 4 other samples, of this series respectively, came within measurable distance of passing the suggested standard.

Neutral-red broth test:

Nottingham.—14 out of 15 effluents passed the standard	Standard, negative result $\frac{1}{1000}$ c.c.
Aldershot Camp.—4 out of 15 effluents passed the standard - - - - - - - - -	
Beddington (Croydon).—4 out of 15 effluents passed the standard - - - - - - - - -	
Leicester.—3 out of 15 effluents§ passed the standard	

* 4 out of 9 effluents, excluding the 1st and 2nd field effluents.
† 4 out of 9 effluents, excluding the 1st and 2nd field effluents.
§ 3 out of 9 effluents, excluding the 1st and 2nd field effluents.

Diagram showing as regards the (1) Gas. (2) B. enteritidis sporogenes. & (3) neutral red broth tests the results of the bacteriological examination of numerous samples of sewage and of effluents obtained from Nottingham, Aldershot, Beddington & Leicester sewage farms: (Special comparative series of experiments.)



The black horizontal line refers in each case to a provisional standard (non-drinking water streams).
The samples are arranged from left to right inversely in the order of their state of biological purity.

Weller & Graham Ltd Litho. London.

As regards Aldershot Camp, Beddington, and Leicester 8; 5; and 5 other samples of this series, respectively, came within measurable distance of passing the suggested standard.

Although the actual, not the percentage results, must be considered in judging sewage effluents, the remarkable purification effected by the land treatment is well worth noting. The contrast between the samples of sewage and of effluents is well shewn in the accompanying diagram. Comparing the effluents from the different sewage farms, it is obvious that the Nottingham effluents were much the best as regards all three tests. Next on the whole come the Aldershot Camp effluents; although the results were, in this case, less satisfactory by the B. enteritidis sporogenes test than as regards the "gas" and neutral red broth tests. Beddington has been given the third place, since the effluents on the average were somewhat better than those obtained from Leicester. Nevertheless, although the worst effluents from Leicester were worse than the worst effluents from Beddington, it should be noted that more effluents from Leicester passed the "gas" and B. enteritidis sporogenes tests than from the Beddington sewage farm. Moreover, samples 350, 351, 358, 359, 362 and 366 from Leicester were not finally treated effluents.

The "gas" test, it will be remembered, affords a simple means of measuring the relative (not the actual) number of gas-forming bacteria present in a sample. The B. enteritidis sporogenes test, apart from its more specialised value, is a most useful indication of the number of sporing anærobes of all sorts present in sewage and sewage effluents. The neutral red broth test, if carried out in the manner recommended by me, is a reliable index of the *probable* number of B. coli or coli-like microbes present.

There can be no question but that these three tests, even taken severally, but more especially when taken collectively, afford a ready and useful means of comparing the biological qualities of sewage effluents and the degree of purification effected by one and another process of sewage treatment.

APPENDIX III.

Showing as regards the (1) "*gas*" ("*gas*" *in gelatine* "*shake*" *cultures in* 24 *hours at* 20° *C.*); *and* (2) *B. enteritidis sporogenes tests the results of the bacteriological examination of numerous samples of sewage and of effluents obtained from various sewage farms.*

In this Appendix all the samples examined by *both* of the above tests are brought into comparison. It must be remembered that the "gas" test, when the observations are made after 24 hours' incubation of the cultures at 20° C., does not give the actual but only the relative number of gas-forming bacteria in the samples. The broad agreement* in the results yielded by the two tests is worth noting. As a rule the samples of sewage give with both tests a positive result with from $\frac{1}{100}$ to $\frac{1}{10000}$ c.c., but usually with $\frac{1}{1000}$ c.c. The sewage effluents naturally varied very much, and the standard set up for both tests, namely, a negative result with $\frac{1}{10}$ c.c. of the sample, practically means that to "pass" this standard the number of spores of B. enteritidis sporogenes and gas-forming bacteria present in crude sewage would require in the effluent to be reduced one-hundred-fold. This may seem a severe standard; but in this connexion, it is worth noting that the really good effluents, as judged by other tests (*e.g.*, those from Nottingham), satisfactorily passed the suggested standard. Indeed, if reference be made to Appendix II. (special comparative series of experiments), it will be seen that nearly all the Nottingham effluents gave a negative result with 1 c.c.; *i.e.*, they not only passed but easily passed the suggested standard (negative result with $\frac{1}{10}$ c.c.).

The following is a brief summary of the results :—

For convenience of description, the "gas" test will be spoken of as (1), and the B. enteritidis sporogenes test as (2):

Leicester.—	1	out of	4	effluents passed test	(1)	Standard as regards tests (1) and (2) negative result $\frac{1}{10}$ c.c. It must, however, be remembered that some of the effluents were not finally treated effluents.
	1	,,	4	,, ,,	(2)	
Nottingham.—	7	out of	8	effluents passed test	(1)	
	7	,,	8	,, ,,	(2)	
South Norwood.—	5	out of	21	effluents passed test	(1)	
	9	,,	21	,, ,,	(2)	
Beddington (*Croydon*).—	4	out of	10	effluents passed test	(1)	
	4	,,	10	,, ,,	(2)	
Aldershot Camp.†—	35	out of	46	effluents passed test	(1)	
	13	,,	46	,, ,,	(2)	
Altrincham.—	9	out of	15	effluents passed test	(1)	
	11	,,	15	,, ,,	(2)	
Rugby.—	9	out of	17	effluents passed test	(1)	
	5	,,	17	,, ,,	(2)	
Cambridge.—	8	out of	14	effluents passed test	(1)	
	2	,,	14	,, ,,	(2)	

The samples examined from Sandhurst, Lindfield, Worsley, Hemsworth and Derby County Asylum sewage farms were too few in number to merit special notice in this place.

In connection with the descriptions of the various sewage farms the above results have already been considered, so that it is unnecessary here to enter into further detail.

---

* By this is meant not that the percentage variation, above and below the mean, showed a parallelism, but only that the results yielded by the two tests showed usually a certain degree of correspondence.

† In the case of Aldershot Camp sewage farm, it would seem as if the gas-forming bacteria were removed or destroyed by the land treatment to a greater extent than the spores of B. enteritidis sporogenes.

TABLE showing as regards (1) the "Gas" Test ("Gas" Production in Gelatine "Shake" Cultures in 24 hours at 20° C.); and (2) the B. Enteritidis Sporogenes Test, the results of the Bacteriological Examination of numerous samples of Sewage and Effluents obtained from various Sewage Farms.

[The double line in each case refers to a provisional standard. According to this standard all samples giving a positive result on the right side of this line would be tentatively condemned.]

Description of the Sample.	"Gas" in Gelatine "Shake" Cultures (24 hours at 20° C.).						Spores of B. Enteritidis Sporogenes (Klein).					
	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.
Leicester Sewage Farm:												
4 General effluent - 14th November 1899.		−						+	−			
145 Final effluent - - 24th September 1900.			+	−				+	−			
146 Final effluent - - 25th September 1900.		+	−					+	−			
147 Final effluent - - 26th September 1900.		+	−				+	−				
Nottingham Sewage Farm:												
10 Crude sewage - - 5th December 1899.				+	−				+	−		
109 Crude sewage - - 23rd July 1900.					+	−			+	−		
11 Final effluent, overworked field. 5th December 1899.			+					+	−			
12 Final effluent - - 5th December 1899.	+	−					−					
110 Final effluent - - 23rd July 1900.	+	−					−					
111 Final effluent - - 24th July 1900.	+	−					−					
113 Final effluent - - 25th July 1900.	−						−					
115 Final effluent - - 30th July 1900.	−						−					
118 Final effluent - - 1st August 1900.	+	−					−					
119 Final effluent - - 1st August 1900.	−						−					
South Norwood Sewage Farm:												
28 Settled sewage - 22nd January 1900.					+	−			+	−		
176 Settled sewage - 20th November 1900.					+	−				+		
25 First effluent - - 16th January 1900.				+	−			+	−			
26 Final effluent - - 16th January 1900.		+	−				+	−				
27 First effluent - - 16th January 1900.				+	−				+	−		
29 Second effluent - 22nd January 1900.		+	−				+	−				
30 Final effluent - - 22nd January 1900.			+	−			+	−				
175 Final effluent - - 14th November 1900.		+	−						+	−		
177 First effluent - - 20th November 1900.				+					+	−		
178 Final effluent - - 20th November 1900.	+	−						+	−			
180 Final effluent - - 21st November 1900	−						+	−				

Description of the Sample.	"Gas" in Gelatine "Shake" Cultures (24 hours at 20° C.).						Spores of B. Enteritidis Sporogenes (Klein)					
	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.
South Norwood Sewage Farm—*continued.*												
Experimental Effluents.												
181 First effluent - - 27th November 1900.			+	−				+	−			
183 First effluent - - 28th November 1900.		+	−					+	−			
184 General effluent - 28th November 1900.		+	−					+	−			
185 Final effluent - - 29th November 1900.	+	−					−					
187 Final effluent - - 3rd December 1900.		+	−					+	−			
181 Final effluent - - 5th December 1900.		+	−				+	−				
190 First effluent - - 10th December 1900.				+						+		
191 Final effluent - - 10th December 1900.		+	−				+	−				
192 Final effluent - - 11th December 1900.	−						+	−				
193 First effluent - - 13th December 1900.		+	−					+	−			
194 Final effluent - - 13th December 1900.	+	−					+	−				
195 Final effluent - - 17th December 1900.		+	−					+	−			
Beddington (Croydon) Sewage Farm:												
40 Crude sewage - - 20th February 1900.				+	−					+	−	
149 Crude sewage - - 3rd October 1900.				+	−					+	−	
152 Crude sewage - - 8th October 1900.					+					+	−	
37 First effluent - - 12th February 1900.				+						+		
38 Second effluent - 12th February 1900.			+	−					+	−		
39 Final effluent - - 12th February 1900.		+	−					+	−			
43 Final effluent - - 20th February 1900.	−						+	−				
150 First effluent - - 3rd October 1900 -				+					+	−		
151 Final effluent - - 3rd October 1900 -			+	−				+	−			
153 Final effluent - - 8th October 1900.				+	−				+	−		
154 Final effluent - - 9th October 1900.		−						−				
155 Final effluent - - 10th October 1900.	+	−					+	−				
157 Final effluent - - 16th October 1900.	+	−					+	−				
Aldershot Camp Sewage Farm:												
48 Crude sewage - - 12th March 1900.					+					+	−	
50 Settled sewage - 14th March 1900.			+	−						+	−	
54 Settled sewage - 21st March 1900.			−							+	−	
81 Settled sewage - 28th May 1900.					+				+	−		
86 Settled sewage - 5th June 1900.				+	−				+	−		
245 Settled sewage - 1st April 1901.				+	−					+	−	
302 Settled sewage - 19th June 1901.				+	−					+	−	
303 Settled sewage - 19th June 1901.				+	−						+	−
306 Settled sewage - 24th June 1901.				+	−					+	−	
314 G. Crude sewage - - 8th July 1901.				+	−					+	−	
319 B. Crude sewage - - 16th July 1901.				+	−					+	−	

Description of the Sample.	"Gas" in Gelatine "Shake" Cultures (24 hours at 20° C.).						Spores of B. Enteritidis Sporogenes (Klein).					
	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.
Aldershot Camp Sewage Farm—*continued.*												
323 A. Crude sewage - 22nd July 1901.				+	−						+	−
325 A. Crude sewage - 24th July 1901.				+	−					+	−	
49 Final effluent - 12th March 1900.	−							+	−			
51 Final effluent - 14th March 1900.	−							+	−			
52 Final effluent - 19th March 1900.	−						+	−				
53 General effluent - 19th March 1900.	+	−						+	−			
55 Final effluent - 21st March 1900.	−							+	−			
(‖) 82 Final effluent - 28th May 1900.		+	−						+			
(‖) 83 Final effluent - 29th May 1900.		+	−					+	−			
(‖) 84 Final effluent - 30th May 1900.		+	−							+		
(‖) 87 Final effluent - 5th June 1900.			+	−					+			
(‖) 88 Final effluent - 6th June 1900.		+	−					+	−			
89 General effluent - 6th June 1900.	−							+	−			
246 General effluent - 1st April 1901.	−							+	−			
247 Final effluent - 1st April 1901.	−						+	−				
304 Final effluent - 19th June 1901.		−						+	−			
305 Final effluent - 19th June 1901.		−							+	−		
¶ 307 Final effluent - 24th June 1901.		−						−				
¶ 312 Final effluent - 2nd July 1901.			+	−						+		
¶ 313 Final effluent - 3rd July 1901.		−						−				
¶ 314 A. Final effluent - 4th July 1901.		−						−				
314 B. Final effluent - 4th July 1901.		−						+				
314 C. Final effluent - 4th July 1901.		−							+	−		
¶ 314 D. Final effluent - 5th July 1901.		−						−				
314 E. Final effluent - 5th July 1901.		−						−				
314 F. Final effluent - 5th July 1901.		−							+	−		
¶ 314 H. Final effluent - 8th July 1901.		−						−				
¶ 317 Final effluent - 9th July 1901.		−						−				
317 A. General effluent - 9th July 1901.		−							+	−		
¶ 318 Final effluent - 10th July 1901.		−						−				
318 A. General effluent - 9th July 1901.		−							+	−		
318 C. General effluent - 11th July 1901.		−						−				
¶ 318 D. Final effluent - 11th July 1901.		−						−				
318 E. General effluent - 12th July 1901.		−							+	−		
¶ 318 F. Final effluent - 12th July 1901.		−						−				
319 Final effluent - 15th July 1901.		+	−						+			
319 A. General effluent - 15th July 1901.		−						+	−			
319 C. Final effluent - 16th July 1901.		−						+	−			
320 A. General effluent - 17th July 1901.		−							+	−		
(‖) 321 Final effluent - 17th July 1901.		−						+	−			
322 A. General effluent - 18th July 1901.		−						+	−			
(‖) 322 Final effluent - 18th July 1901.		+	−						+	−		

(‖) Signifies new land effluents (A).
¶ " " " (B).

Description of the System.	"Gas" in Gelatine "Shake" Cultures (24 hours at 20° C.).						Spores of B. Enteritidis Sporogenes (Klein).					
	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	0001 c.c.	·00001 c.c.
Aldershot Camp Sewage Farm—*continued.*												
322 B. General effluent - 19th July 1901.		+	−						+	−		
322 C. Final effluent - - 19th July 1901.		−						+	−			
(III) 323 General effluent - 22nd July 1901.			+	−					+	−		
323 B. General effluent - 22nd July 1901.		−						+	−			
(III) 324 Final effluent - - 23rd July 1990.			+	−					+	−		
324 A. General effluent - 23rd July 1901.		−						+	−			
Altrincham Sewage Farm:												
64 Settled sewage - 26th April 1900.		+	−						+	−		
65 First effluent from lagoon. 26th April 1900.				+	−				+	−		
69 Ponded lagoon liquor 30th April 1900.			+	−				+	−			
75 Settled sewage - 15th May 1900.			+	−					+	−		
249 Settled sewage - 17th April 1901.			+	−				+	−			
264 Settled sewage - 30th April 1901.				+	−				+	−		
265 First lagoon liquor - 30th April 1901.				+					+	−		
266 Second lagoon liquor 30th April 1901.				+				+	−			
275 Liquor last lagoon - 8th May 1901.				+	−				+	−		
66 Final effluent - - 26th April 1900.		−					−					
70 Effluent, ponded lagoon. 30th April 1900.		+	−				+	−				
72 General effluent - 7th May 1900.		+	−				+	−				
76 Final effluent - - 15th May 1900.		+	−					+	−			
77 Final effluent - - 16th May 1900.		+	−					+	−			
248 Final effluent - - 16th April 1900.		+	−					+	−			
250 Final effluent - - 17th April 1900.		+	−					+	−			
251 Final effluent - - 17th April 1900.	+	−					+	−				
252 Final effluent - - 22nd April 1900.	+	−					+	−				
253 Final effluent - - 22nd April 1900.	+	−					+	−				
254 Final effluent - - 22nd April 1900.	+	−					+	−				
255 Final effluent - - 22nd April 1900.	+	−					+	−				
267 Final effluent - - 1st May 1901.	+	−					+	−				
274 Final effluent - - 7th May 1901.	+	−					+	−				
276 Final effluent - - 8th May 1901.	+	−					+	−				
Rugby Sewage Farm:												
93 Crude sewage - - 19th June 1900.			+	−						+	−	
97 Crude sewage - - 25th June 1900.				+	−					+	−	
233 Crude sewage - - 6th March 1901.				+	−				+	−		
235 Crude sewage - - 11th March 1901.				+	−					+	−	
95 Chemically precipitated sewage. 20th June 1900.			+	−					+	−		

Description of the Sample.	"Gas" in Gelatine 'Shake" Cultures (24 hours at 20° C.).						Spores of B. Enteritidis Sporogenes (Klein).					
	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.
Rugby Sewage Farm—*continued.*												
101 Chemically precipitated sewage. 2nd July 1900.				+	−					+	−	
224 Settled sewage - 18th February 1901.			+	−						+	−	
94 Final effluent - - 19th June 1900.			+	−					+	−		
96 Final effluent - - 20th June 1900.	+	−						+	−			
98 Final effluent - - 25th June 1900.			+	−				+	−			
102 Final effluent - - 2nd July 1900.			+	−				+				
103 Final effluent - - 3rd July 1900.			+	−					+	−		
104 Final effluent - - 4th July 1900.			+	−				+	−			
106 General effluent - 9th July 1900.		+	−				−					
225 General effluent - 18th February 1901.	+	−						+	−			
226 Final effluent - - 20th February 1901.	+	−						+	−			
228 First effluent - - 26th February 1901.			+	−					+	−		
229 Final effluent - - 26th February 1901.	+	−					+	−				
230 General effluent - 27th February 1901.	+	−						+	−			
232 Final effluent - - 5th March 1901.	−						+	−				
234 General effluent - 6th March 1901.	+	−						+	−			
236 First effluent - - 11th March 1901.			+	−					+	−		
237 General effluent - 11th March 1901.	−						+	−				
238 General effluent - 13th March 1901.	−						+	−				
Cambridge Sewage Farm:												
201 Crude sewage - - 8th January 1901.			+	−					+	−		
213 Settled sewage 23rd January 1901.			+	−					+	−		
215 Settled sewage - 28th January 1901.			+	−					+	−		
217 Settled sewage - 28th January 1901.			+	−					+	−		
203 Final effluent - - 9th January 1901.		+	−					+	−			
204 General effluent - 9th January 1901.		+	−					+	−			
205 General effluent - 10th January 1901.		+	−						+	−		
207 General effluent - 14th January 1901.	+	−						+	−			
208 General effluent - 15th January 1901.		+	−					+	−			
209 General effluent - 16th January 1901.		+	−					+	−			
210 Final effluent - - 16th January 1901.	−							+	−			
211 Final effluent - - 21st January 1901.	+	−					+	−				
212 Final effluent - - 21st January 1901.	+	−						+	−			
214 General effluent - 23rd January 1901.		+	−					+	−			
216 Final effluent - - 28th January 1901.	−							+	−			
218 Final effluent - - 28th January 1901.	−						+	−				
220 General effluent - 4th February 1901.	+	−						+	−			
221 General effluent - 5th February 1901.	+	−						+	−			

Description of the Sample.	"Gas" in Gelatine "Shake" Cultures (24 hours at 20° C.).						Spores of B. Enteritidis Sporogenes (Klein).					
	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.
Sandhurst Sewage Farm:												
61 Settled sewage - 4th April 1899.				+	−				+	−		
62 First effluent - - 4th April 1900.			+	−				+	−			
63 Final effluent - - 4th April 1900.			+	−					+	−		
Lindfield Sewage Farm:												
91 Settled sewage - 12th June 1900.				+	−					+	−	
92 Final effluent - - 12th June 1900.		+	−					+	−			
Worsley Sewage Farm:												
277 Crude sewage - - 13th May 1901.					+				+	−		
285 Crude sewage - - 28th May 1901.				+	−				+	−		
278 Final effluent - - 13th May 1901.			+	−			+	−				
280 Final effluent - - 15th May 1901.			+	−			+	−				
286 Final effluent - - 28th May 1901.		+	−				No record.					
287 Final effluent - - 28th May 1901.	+	−					+	−				
Hemsworth Sewage Farm:												
291 Settled sewage - 4th June 1901.				+	−				+	−		
293 Crude sewage - - 5th June 1901.					+					+	−	
292 Final effluent - - 4th June 1901.				+	−				+	−		
294 Final effluent - 5th June 1901.					+			+	−			
Mickleover Asylum Sewage Farm:												
295 Crude sewage - - 11th June 1901.			+	−				+	−			
296 Final effluent - - 11th June 1901.		−						+	−			
297 Final effluent - - 12th June 1901.		+						+	−			
298 Final effluent - - 12th June 1901.		+	−					+	−			

C.

Diagram showing as regards (1) the gas test & (2) the B. enteritidis sporogenes test the result of the bacteriological examination of numerous Samples of Sewage & of Effluents from Various Sewage Farms.

E. Walter & Grahams, Ltd Litho. London

APPENDIX IV.

Showing as regards (1) *the neutral red broth,* (2) *litmus milk,* (3) *B. enteritidis sporogenes, and* (4) *"gas" tests the results of the bacteriological examination of numerous samples of sewage and effluent obtained from various sewage farms.*

In this Appendix, the results obtained by the use of these four simple tests are brought into comparison. It will be seen, from the accompanying table and diagram, that a broad parellelism* exists between these tests. The neutral red broth and litmus milk tests run more or less together and show a wider range of results than the "gas" and B. enteritidis sporogenes tests. Carried out in the way that has been recommended, these tests afford a useful indication of the probable number of coli-like microbes present in a sample. But apart from the precise interpretation to be placed on the results, that is, on the identity of the particular microbes producing certain changes in these media, these changes being recorded as positive results, there can be no question that the tests, *as tests*, are of considerable value in enabling one to gauge the biological *status* of sewage effluents and the degree of purification effected by one and another system of treatment. The importance of this way of looking at and judging bacteriological tests has been repeatedly emphasized; and it is only necessary to add that the above remarks apply equally well to the "gas" and B. enteritidis sporogenes tests. These tests ("gas" test and B. enteritidis test), of course, run at a lower level, that is, they show a narrower range of results than, for instance, does the neutral red broth test; and in respect of the "gas" test it must be remembered that the results, as observed after 24 hours at 20° C., *do not indicate the actual but the relative number* of gas-forming bacteria of the B. coli and B. proteus class. Since the work covered by this report was in progress the litmus milk test has been modified,† and the time of observation, both for the litmus milk and neutral red broth test, extended to 48 hours. The standard for the former test has been brought to the same level as the neutral red broth test, viz., a negative result with $\frac{1}{1000}$ c.c. of the sample.

In judging the results obtained by the treatment of sewage on land of one or another kind, it is important to note that crude sewage, when submitted to the neutral red broth and litmus milk tests, usually gives a positive result with $\frac{1}{10000}$ to $\frac{1}{100000}$ c.c.; and a positive result with usually $\frac{1}{1000}$ c.c. in respect of the "gas" and B. enteritidis sporogenes tests.

The remarkable percentage improvement effected in the effluents as compared with the sewage by the land treatment is striking; but it must always be remembered that the actual, not the percentage, result is the true criterion of safety and purity. Nevertheless, the fact that many of the effluents showed a hundred-fold and some a thousand-fold purification, as compared with the crude sewage, is well worth noting.

The following is a brief summary of the results:—

The neutral red broth, litmus milk, B. enteritidis sporogenes, and "gas" tests will be referred to as tests (1), (2), (3), and (4) respectively. Taken in the same order the standards are a negative result with ·001, ·01, ·1, and ·1 c.c. respectively.

Rugby Sewage Farm:—Crude sewage: Sample (235) gave a positive result with $\frac{1}{100000}$ c.c.; $\frac{1}{10000}$ c.c.; $\frac{1}{1000}$ c.c.; and $\frac{1}{100}$ c.c. as regards tests (1), (2), (3), (4) respectively. *Effluents:* All three effluents passed the standards for tests (1), (3), and (4), and one out of these three effluents the standard for test (2).

Aldershot Camp Sewage Farm:—Crude sewage: All the eight samples of sewage gave a positive result with $\frac{1}{100000}$ c.c., test (1). Six out of seven a positive result with $\frac{1}{100000}$ c.c., test (2). As regards test (3), two samples gave a positive result with $\frac{1}{10000}$ c.c., and the remaining six a positive result with $\frac{1}{1000}$ c.c. All eight samples gave a positive result with $\frac{1}{1000}$ c.c., test (4).

* By a "broad parallelism" is not meant an agreement as regards percentage variation, above and below the mean, but only that the curves relating to these tests show some degree of correspondence.

† Milk, 20%; peptone, 2%; lactose, 1%; sodium taurocholate, 0·5% (very similar results are obtained if this salt is omitted); sodium carbonate 0·01%; water, 76·5%; tinted with litmus solution. Observations as regards "gas" formation, acitity and clotting made after 24 to 48 hours incubation at 37° C. Later, I have used with success this medium, but with 0.1 per cent of sodium carbonate and no sodium taurocholate.

Effluents : As regards test (1), 19 out of 35 samples passed the standard set up for this test; 15 out of 33 proved satisfactory in respect of test (2); 12 out of 35 passed the standard for test (3); 29 out of 35 passed as regards test (4).

Altrincham Sewage Farm :—Sewages and ponded liquor ; Sample 249 (settled sewage) gave positive result with $\frac{1}{10000}$ c.c., test (1); $\frac{1}{1000}$ c.c., test (2); $\frac{1}{10}$ c.c., test (3); $\frac{1}{100}$ c.c., test (4 Sample 264 (settled sewage) gave a positive result with $\frac{1}{100000}$ c.c., test (1); $\frac{1}{1000}$ c.c., test (2); $\frac{1}{100}$ c.c., test (3); $\frac{1}{1000}$ c.c., test (4). The ponded liquor 266 gave as regards tests (1), (2), (3), (4) a positive result with, respectively, $\frac{1}{1000}$ c.c.; $\frac{1}{100}$ c.c.; $\frac{1}{10}$ c.c.; and $\frac{1}{1000}$ c.c. *Effluents :* As regards the effluents, 3 out of 4; 2 out of 3; 2 out of 4; 2 out of 4 samples passed the standards set up for tests (1), (2), (3), (4) respectively.

Worsley Sewage Farm :—Crude sewage ; Sample 277 gave as regards tests (1), (2), (3), (4) a positive result with, respectively, $\frac{1}{100000}$ c.c.; $\frac{1}{1000}$ c.c.; $\frac{1}{100}$ c.c. and $\frac{1}{10000}$ c.c. Taking the tests in the same order, sample 285 gave a positive result with $\frac{1}{100000}$ c.c.; $\frac{1}{10000}$ c.c.; $\frac{1}{100}$ c.c.; and $\frac{1}{1000}$ c.c. *Effluents :* As regards the effluents, keeping this order, 1 out of 3; 1 out of 3; all 3; 1 out of 3 samples passed the standards set up for tests (1), (2), (3), (4) respectively.

Derby County Asylum (Mickleover) Sewage Farm .—Crude sewage : Sample 295 gave as regards tests (1), (2), (3), (4) a positive result with $\frac{1}{100000}$ c.c.; $\frac{1}{10000}$ c.c.; $\frac{1}{10}$ c.c.; and $\frac{1}{100}$ c.c. respectively. *Effluents :* Taking the tests in the same order, none out of 3; 1 out of 3; none out of 3; and 1 out of 3 samples passed the standards set up for these tests.

The above results have been already dealt with in connexion with the descriptions of Rugby, Aldershot Camp, Altrincham, Worsley and Derby County Asylum (Mickleover) sewage farms; it is, therefore, unnecessary to consider them here in greater detail.

TABLE showing as regards the (1) Neutral red broth; (2) Litmus milk; (3) B. enteritidis sporogenes; and (4) "Gas" tests, the results of the bacteriological examination of numerous samples of sewage and effluents obtained from various sewage farms.

[The double thin line in each case refers to a provisional standard, and the effluents giving a positive result on the right side of the line would be tentatively condemned.]

Description of Sample.	Neutral red broth test (24 hours at 37° C.):—Greenish yellow fluorescence = positive result (+). No change in colour = negative result (−).						Litmus milk test (24 hours at 37° C.):—Strong acid and solid clot, positive result (+). Distinct acidity but no clot, result not wholly negative (? −). Little or no visible change, negative result (−).						Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures).						"Gas" in gelatine "shake" cultures (24 hours at 20° C.).					
	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.
RUGBY SEWAGE FARM.	(Standard, negative result with $\frac{1}{1000}$ c.c.)						(Standard, negative result with $\frac{1}{100}$ c.c.)						(Standard, negative result with $\frac{1}{10}$ c.c.)						(Standard, negative result with $\frac{1}{10}$ c.c.)					
235 Crude Sewage - - - 11th March 1901.						+					+	? −				+	−				+	−		
232 Final effluent - - - 5th March 1901.			+	−				+	−				+	−					−					
237 General effluent - - - 11th March 1901.			+	−					+	−			+	−					−					
238 General effluent - - - 13th March 1901.			+	−					+	? −			+	−					−					
ALDERSHOT CAMP SEWAGE FARM.																								
245 Settled sewage - - - 1st April 1901.						+	No record.									+	−					+	−	
302 Settled sewage - - - 12th June 1901.						+						+				+	−					+	−	
303 Settled sewage - - - 12th June 1901.						+					+	? −					+	−				+	−	
306 Settled sewage - - - 24th June 1901.						+						+				+	−					+	−	
314 G. Crude sewage - - - 8th July 1901.						+						+				+						+	−	
319 B. Crude sewage - - - 16th July 1901.						+						+				+	−					+	−	

TABLE showing as regards the (1) Neutral red broth; (2) Litmus milk; (3) B. enteritidis sporogenes; and (4) "Gas" tests, &c.—*continued.*

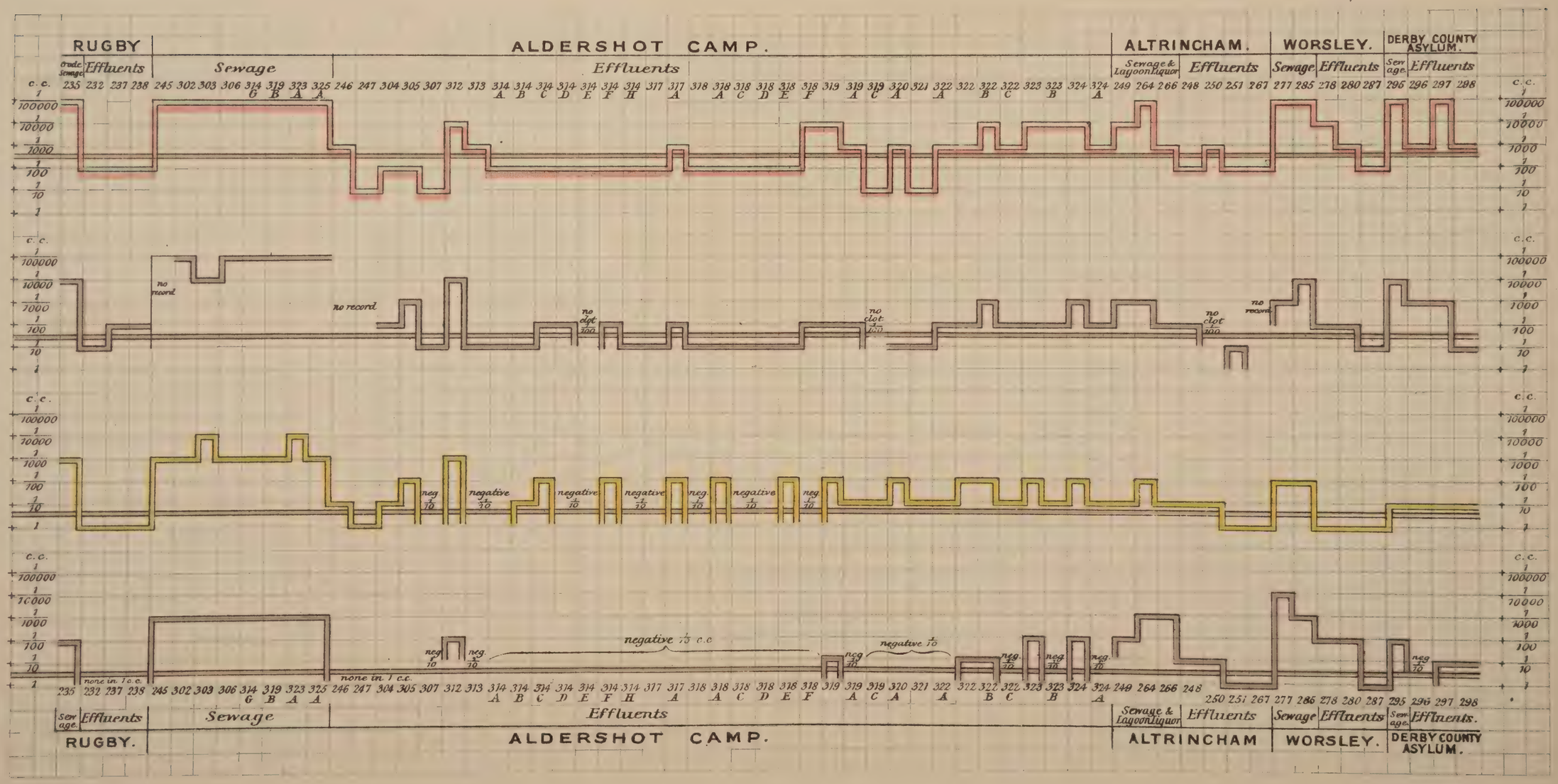
Description of Sample.	Neutral red broth test (24 hours at 37° C.):—Greenish yellow fluorescence = positive result (+). No change in colour = negative result (−).						Litmus milk test (24 hours at 37° C.):—Strong acid and solid clot, positive result (+). Distinct acidity but no clot, result not wholly negative (?−). Little or no visible change, negative result (−).						Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk culture).						"Gas" in gelatine "shake" cultures (24 hours at 20° C.).					
	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.
Aldershot Camp Sewage Farm—*cont.*	(Standard, negative result with $\frac{1}{100}$ c.c.)						(Standard, negative result with $\frac{1}{100}$ c.c.)						(Standard, negative result with $\frac{1}{10}$ c.c.)						(Standard, negative result with $\frac{1}{10}$ c.c.)					
323 A. Crude sewage - - - 22nd July 1901.						+						+					+	−				+	−	
325 A. Crude sewage - - - 24th July 1901.						+						+				+	−					+	−	
246 General effluent - - - 1st April 1901.				+	−				No record.					+	−				−					
247 Final effluent - - - 1st April 1901.		+	−						No record.				+	−					−					
304 Final effluent - - - 19th June 1901.			+	−					+	?−	?−			+	−				−					
305 Final effluent - - - 19th June 1901.			+	−						+	−				+	−			−					
307 Final effluent - - - 24nd June 1901.		+	−					+	−					−						−				
312 Final effluent - - - 2nd July 1901.					+						+					+	−				+	−		
313 Final effluent - - - 3rd July 1901.		-		+	−			+	?−	−				−						−				
314 A. Final effluent - - - 4th July 1901.			+	−				+	?−	−				−						−				
314 B. Final effluent - - - 4th July 1901.			+	−				+	?−	−				+	−					−				
314 C. Final effluent - - - 4th July 1901.			+	−					+	?−	?−				+	−				−				
314 D. Final effluent - - 5th July 1901.			+	−					+	−				−						−				
314 E. Final effluent - - - 5th July 1901.			+	−					?−	−				−						−				
314 F. Final effluent - - - 5th July 1901.			+	−					+	?−	−				+	−				−				
314 H. Final effluent - - - 8th July 1901.			+	−				+	?−	−				−						−				

317	Final effluent 9th July 1901.			+					+	?−	−				−								−					
317 A.	General effluent 9th July 1901.				+	−				+	?−	−				+	−						−					
318	Final effluent 10th July 1901.			+	−				+	?−	−				−								−					
318 A.	General effluent 9th July 1901.			+	−				+	?−	−					+	−						−					
318 C.	General effluent 11th July 1901.			+	−				+	?−	?−	−			−								−					
318 D.	Final effluent 11th July 1901.			+	−				+	−					−								−					
318 E.	General effluent 12th July 1901.			+	−				+	?−	−					+	−						−					
318 F.	Final effluent 12th July 1901.					+				+	?−	?−			−								−					
319	Final effluent 15th July 1901.					+				+	?−	?−				+	−						+	−				
319 A.	General effluent 15th July 1901.				+	−				+	?−	?−			+	−							−					
319 C.	Final effluent 16th July 1901.		+	−						?−	−				+	−							−					
320 A.	General effluent 17th July 1901.				+	−			+	?−	?−	−				+	−						−					
321	Final effluent 17th July 1901.		+	−					+	?−	?−	−			+	−							−					
322 A.	General effluent 18th July 1901.				+	−				+	?−	−			+	−							−					
322	Final effluent 18th July 1901.				+	−				+	?−	−				+	−						+	−				
322 B.	General effluent 19th July 1901.					+					+	?−				+	−						+	−				
322 C.	Final effluent 19th July 1901.				+	−				+	?−	?−			+	−							−					
323	Final effluent 22nd July 1901.					+				+	?−	?−				+	−							+	−			
323 B.	General effluent 22nd July 1901.					+				+	?−	?−			+	−							−					
324	Final effluent 23rd July 1901					+					+	?−				+	−							+	−			
324 A.	General effluent 23rd July 1901.				+	−				+	?−	?−			+	−							−					
Altrincham Sewage Farm:																												
249	Settled sewage 17th April 1901.					+	−				+	?−	?−		+	−								+	−			
264	Settled sewage 30th April 1901.						+				+	?−	?−			+	−								+	−		

TABLE showing as regards the (1) Neutral red broth; (2) Litmus milk; (3) B. enteritidis sporogenes; and (4) "Gas" tests, &c.—*continued.*

Description of Sample.	Neutral red broth test (24 hours at 37° C.):—Greenish yellow fluorescence = positive result. (+) No change in colour = negative result (−).						Litmus milk test (24 hours at 37° C.):—Strong acid and solid clot, positive result (+). Distinct acidity but no clot, result not wholly negative (?−). Little or no visible change, negative result (−).						Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk culture).						"Gas" in gelatine "shake cultures (24 hours at 20° C.).					
	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	01 c.c.	.001 c.c.	·0001 c.c.	·00001 c.c.
Altrincham Sewage Farm — *continued.*	(Standard, negative result with $\frac{1}{1000}$ c.c.)						(Standard, negative result with $\frac{1}{100}$ c.c.)						(Standard, negative result with $\frac{1}{10}$ c.c.)						(Standard, negative result with $\frac{1}{10}$ c.c.)					
266 Second lagoon liquor - - 30th April 1901.				+					+	?−				+	−							+		
248 Final effluent - - - 16th April 1901.			+	−					+	?−				+	−					+	−			
250 Final effluent - - - 17th April 1901.				+	−				?−	−				+	−					+	−			
251 Final effluent - - - 17th April 1901.			+	−				+	?−	−			+	−					+	−				
267 Final effluent - - - 1st May 1901.			+	−					No record.				+	−					+	−				
WORSLEY SEWAGE FARM:																								
277 Crude sewage - - - 13th May 1901.						+				+	?−	?−			+	−							+	
285 Crude sewage - - - 28th May 1901.						+					+	?−			+	−						+	−	
278 Final effluent - - - 13th May 1901.					+				+	?−	?−		+	−							+	−		
280 Final effluent - - - 15th May 1901.				+	−				+	?−	?−		+	−							+	−		
287 Final effluent - - - 28th May 1901.			+	−				+	?−	?−			+	−					+	−				
MICKLEOVER SEWAGE FARM: (Derby County Asylum.)																								
295 Crude sewage - - - 11th June 1901.						+					+	?−		+	−						+	−		
296 Final effluent - - - 11th June 1901.				+	−					+	?−			+	−					−				
297 Final effluent - - - 12th June 1901.						+				+	?−	−		+	−					+	−			
298 Final effluent - - - 12th June 1901.				+	−			+	?−	?−	?−			+	−					+	−			

Diagram showing as regards the (1) neutral red broth; (2) litmus milk; (3) B. enteritidis sporogenes; & (4) "gas" tests the results of the bacteriological examination of samples of sewage & of effluents from Rugby, Aldershot Camp, Altrincham, Worsley & Derby County Asylum sewage farms.



Weller & Graham Ltd Litho. London.

APPENDIX V.

Showing the results of the bacteriological examination of average samples (24 hours, collected hourly) of Beddington, South Norwood, Aldershot Camp, Nottingham, Leicester, Rugby, and Cambridge sewage.

During the early part of 1902 Dr. McGowan arranged for the collection of average samples (24 hours, collected hourly) of sewage from the above mentioned places. These sewages he proposed to examine by special chemical processes in order to elucidate some problems of importance from the chemical and practical points of view. The mode of collection of the samples and other factors of interest are dealt with fully in his report, (Part II., Chemical Report) and so need not be repeated here. Bacteriologically considered, the samples were of less value, but it was thought desirable to examine a number of them in order to obtain parallel chemical and bacteriological records.

The tests employed for this purpose were as follows :—

Total number of bacteria { gelatine at 20° C. / agar at 37° C.
Number of B. coli.
Indol test.
B. enteritidis sporogenes test.
"Gas" test.
Bile salt broth test.
Neutral red broth test.

All of these tests, however, were not made use of in the case of every sample.

The results are set forth in the appended table and diagram.

The following is a brief summary of the result :—

29 samples were examined in all : 7 from Beddington (crude sewage) : 7 from South Norwood (settled sewage) ; 3 from Aldershot Camp (screened and settled) ; 3 from Nottingham (screened, mixed with crude) ; 3 from Leicester (screened and settled) ; 3 from Rugby (screened and settled) ; and 3 from Cambridge (screened and settled).

As regards the Beddington samples the number of bacteria per c.c. was on the average over ten millions but under one hundred millions (gelatine at 20° C.) and over one million but less than ten millions (agar at 37° C.). The number of B. coli and indol producing bacteria was usually at least 100,000 per c.c. One sample examined as regards the B. enteritidis sporogenes ; "gas" ; bile-salt broth ; and neutral red broth tests gave the following results :— + $\frac{1}{100}$ c.c. ; + $\frac{1}{1000}$ c.c. ; + $\frac{1}{100000}$ c.c. respectively.

The South Norwood samples yielded somewhat lower results as regards the total number of bacteria. The number of B. coli and indol-producing bacteria varied from 10,000 to 100,000 per c.c. The B. enteritidis sporogenes test with one exception gave a positive result with $\frac{1}{1000}$ c.c. The "gas" test with one exception gave a positive result with $\frac{1}{100}$ c.c. The bile salt broth (in every case) and the neutral red broth (usually) gave a positive result with $\frac{1}{100000}$ c.c.

As regards the Aldershot Camp, Nottingham, Leicester, Rugby, and Cambridge samples the results may be summarised as follows :—

Usually the number of bacteria per c.c. was over ten millions (gelatine at 20° C.) and over one million (agar at 37° C.). The number of B. coli and indol-producing bacteria varied from 10,000 to 100,000 per c.c. The B. enteritidis sporogenes test usually gave a positive result with $\frac{1}{100}$ to $\frac{1}{1000}$ c.c. and the "gas" test with $\frac{1}{10}$ to $\frac{1}{100}$ to $\frac{1}{1000}$ c.c. The "gas" test

yielded low results with both the Aldershot Camp and Leicester sewages. The bile salt broth test always gave a positive result with $\frac{1}{100000}$ c.c. and the neutral red broth test with from $\frac{1}{10000}$ to $\frac{1}{100000}$ c.c.

This opportunity may be taken to point out that domestic sewage and mixed sewage, when the trade refuse is not of such amount or quality as to alter materially the biological qualities of the mixed liquid, commonly give bacteriological results as follows :—

Total number of bacteria (gelatine at 20° C.) : — More than ten million, but less than one hundred million bacteria per c.c.

Total number of bacteria (agar at 37° C.) :—More than one million, but less than ten million bacteria per c.c.

B. coli (and closely allied forms) :—About 100,000 in 1 c.c.

Indol producing bacteria ,, ,,

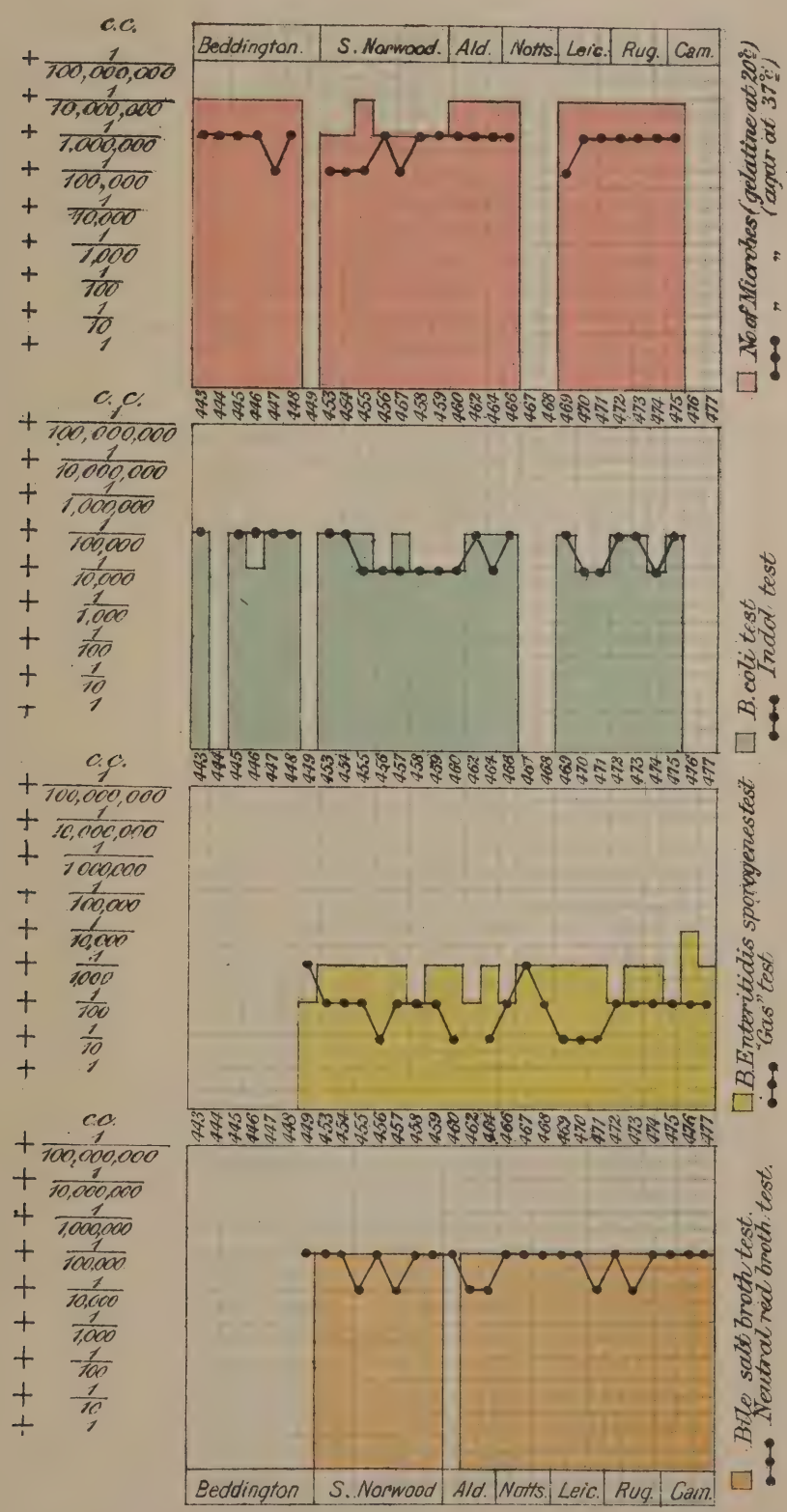
Spores of B. enteritidis sporogenes :—100 to 1,000 per c.c.

"Gas" test : —Usually a positive result with $\frac{1}{100}$ to $\frac{1}{1000}$ c.c.

Bile-salt broth test :—
Neutral red broth test :— } Usually a positive result with $\frac{1}{100000}$ c.c.

The average samples above described yielded bacteriological results agreeing closely with this general statement.

Diagram showing the results of the bacteriological examination of Samples of Beddington, South Norwood, Aldershot Camp, Nottingham, Leicester, Rugby & Cambridge Sewage.



Weller & Graham Ltd Litho.

TABLE.—Showing the results of the bacteriological examination of samples of Beddington, South Norwood, Aldershot Camp, Nottingham, Leicester, Rugby, and Cambridge Sewage.

Description of the Sample.	Total Number of Bacteria per c.c.		Number of B. coli per C.C.	Indol test (indol in broth cultures 5 days at 37° C.	B. enteritidis sporogenes test.	"Gas" test (gas in gelatine "shake" cultures, 24 hours as 20° C.	Bile-salt broth test (2 days at 45° C.)	Neutral red broth test (2 days at 37° C.
	Gelatine at 20° C.	Agar at 37° C.						
443. BEDDINGTON crude sewage, average 24 hours 1/1/02.	22,400,000	1,968,000	100,000	+ $\frac{1}{100,000}$ c.c.	—	—	—	—
444. 2/1/02. " " "	32,500,000	2,880,000	—	" "	—	—	—	—
445. 3/1/02. " " "	18,200,000	2,810,000	100,000	" "	—	—	—	—
446. 4/1/02. " " "	27,400,000	5,960,000	10,000	" "	—	—	—	—
447. 5/1/02. " " "	13,100,000	840,000	100,000	" "	—	—	—	—
448. 6/1/02. " " "	13,600,000	1,120,000	100,000	" "	—	—	—	—
449. 7/1/02. " " "	—	—	—	—	+ $\frac{1}{100}$ c c.	+ $\frac{1}{1,000}$ c.c.	—	+ $\frac{1}{100,000}$ c.c.
453. SOUTH NORWOOD, settled sewage, average 24 hours. 11/1/02.	8,900,000	430,000	100,000	+ $\frac{1}{100,000}$ c c	+ $\frac{1}{1,000}$ c.c.	+ $\frac{1}{100}$ c.c.	+ $\frac{1}{100,000}$ c.c.	+ $\frac{1}{100,000}$ c.c.
454. 13/1/02. " " "	9,900,000	380,000	100,000	" "	" "	" "	" "	" "
455. 16/1/02. " " "	14,200,000	760,000	100,000	+ $\frac{1}{10,000}$ c.c.	" "	" "	" "	+ $\frac{1}{10,000}$ c.c.
456. 17/1/02. " " "	8,700,000	1,360,000	10,000	" "	" "	+ $\frac{1}{10}$ c.c.	" "	+ $\frac{1}{100,000}$ c.c
457. 18/1/02. " " "	5,600,000	630,000	100 000	" "	" "	+ $\frac{1}{100}$ c.c.	" "	+ $\frac{1}{10,000}$ c.c.
458. 19/1/02. " " "	5,700,000	1,640,000	10,000	" "	+ $\frac{1}{100}$ c.c.	" "	" "	+ $\frac{1}{100,000}$ c.c.
459. 20/1/02. " " "	7,400,000	1,360,000	10,000	" "	+ $\frac{1}{1,000}$ c.c.	" "	" "	" "
460. ALDERSHOT CAMP screened and settled sewage, average 24 hours. 28/1/02.	28,400,000	4,100,000	10,000	+ $\frac{1}{10,000}$ c.c.	+ $\frac{1}{1,000}$ c.c.	+ $\frac{1}{10}$ c.c.	—	+ $\frac{1}{100,000}$ c.c
462. 29/1/02. " " "	17,100,000	2,230,000	100,000	+ $\frac{1}{100,000}$ c.c.	+ $\frac{1}{100}$ c.c.	— $\frac{1}{10}$ c.c.	+ $\frac{1}{100,000}$ c.c.	+ $\frac{1}{10,000}$ c.c
464. 30/1/02. " " "	33,400,000	8,830,000	100,000	+ $\frac{1}{10,000}$ c.c.	+ $\frac{1}{1,000}$ c.c.	+ $\frac{1}{10}$ c.c.	" "	"
466. NOTTINGHAM screened (mixed crude) sewage, average 24 hours. 2/2/02.	10,900,000	1,330,000	100,000	+ $\frac{1}{100,000}$ c.c.	+ $\frac{1}{100}$ c.c.	+ $\frac{1}{100}$ c.c.	+ $\frac{1}{100,000}$ c.c.	+ $\frac{1}{100,000}$
467. 3/2/02. " " "	—	—	—	—	+ $\frac{1}{1,000}$ c.c.	+ $\frac{1}{1,000}$ c.c.	" "	"
468. 4/2/02. " " "	—	—	—	--	" "	+ $\frac{1}{100}$ c.c.	" "	"
469. LEICESTER screened and settled sewage, average 24 hours. 11/2/02.	16,000,000	680,000	100,000	+ $\frac{1}{100,000}$ c.c.	+ $\frac{1}{1,000}$ c.c.	+ $\frac{1}{10}$ c.c.	+ $\frac{1}{100,000}$ c.c.	+ $\frac{1}{100,000}$ c.c.
470. 12/2/02. " " "	10,200,000	1,020,000	10,000	+ $\frac{1}{10,000}$ c.c.	" "	" "	" "	" "
471. 13/2/02. " " "	17,500,000	2,160,000	" "	" "	" "	" "	" "	+ $\frac{1}{10,000}$ c c.
472. RUGBY screened and settled sewage, average 24 hours. 18/2/02.	20,400,000	1,860,000	100,000	+ $\frac{1}{100,000}$ c.c.	+ $\frac{1}{100}$ c.c.	+ $\frac{1}{100}$ c.c.	+ $\frac{1}{100,000}$ c.c.	+ $\frac{1}{100 000}$ c.c.
473. 19/2/02. " " "	26,200,000	1,780,000	100,000	" "	+ $\frac{1}{1,000}$ c.c.	" "	" "	+ $\frac{1}{10,000}$ c.c.
474. 20/2/02. " " "	29,900,000	2,860,000	10,000	+ $\frac{1}{10,000}$ c.c.	" "	"	" "	+ $\frac{1}{100,000}$ c.c.
475. CAMBRIDGE screened and settled sewage, average 24 hours. 25/2/02.	13,500,000	1,360,000	100,000	+ $\frac{1}{100,000}$ c.c.	+ $\frac{1}{100}$ c.c.	+ $\frac{1}{100}$ c.c.	+ $\frac{1}{100,000}$ c.c.	+ $\frac{1}{100,000}$ c.c.
476. 26/2/02. " " "	—	—	—	—	+ $\frac{1}{10,000}$ c.c.	" "	" "	" "
477. 27/2/02. " " "	—	—	—	—	+ $\frac{1}{1,000}$ c.c.	" "	" "	" "

APPENDIX VI.

Showing, as regards the neutral red broth test (a) "*ordinary*," *and* (b) "*spore*" *curves; and the indol test* (a) "*ordinary*" *and* (b) "*spore*" *curves, the results of the bacteriological examination of* 25 *samples of sewage and effluent.*

The appended diagram explains itself, but it may be as well to point out that neither the neutral red broth nor the indol tests are *specific* tests for B. coli. There are, in sewage and effluents, sporing bacteria which are capable of yielding positive results with both these tests. As, however, the spores, when compared with the enormous number of coli-like microbes, are very few in number, it is found in practice that if the *smallest amount* of a sewage or effluent capable of yielding a positive result with these tests be determined, the presumptive evidence in favour of coli-like microbes being responsible for the change (positive result) is apt to be of a strong kind. It is true that some bacilli (other than B. coli), as well as the spores of bacteria, have been credited with ability to yield a positive result with either or both of these tests. But in sewage and effluents, these microbes, probably inferior in numbers to B. coli, are always accompanied by coli-like microbes, and are themselves no unreliable index of the biological qualities of a sample. Indeed the neutral red broth and indol tests, *as tests*, are of real value in the bacteriological examination of sewage and effluents, apart altogether from the precise interpretation to be placed on the results, in relation to the particular microbes concerned in producing the change (positive result) observed in the media employed for these processes. For a negative or positive result in relation to the amount of the sample used for cultural purposes is a most useful index of the relative state of purity or impurity, as the case may be, of the sample, apart altogether from the vexed question of the identity of the microbes concerned in the process.

As a matter of fact, allowing for experimental error, which in bacteriological processes is apt to be not inconsiderable, the broad parallelism between the neutral red broth, indol, and B. coli tests is striking. This correspondence is shown incidentally in the appended diagram, although the experiments were not primarily carried out to demonstrate this point, which, indeed, is borne out by other records much more numerous than those here presented. They were intended to show that there is a wide difference between the (*a*) "ordinary" and (*b*) "spore" curves of the (1) neutral red broth and (2) the indol test. In other words, that the "spore" curve runs at a much lower level than the "ordinary" curve as regards both these tests. These results might, perhaps, have been anticipated from my reports made respectively to the Local Government Board and London County Council on the bacteriology of soils and sewage. In these reports it has been shown that, on the one hand in soils the spores, both actually and in relation to the total number of bacteria, are very numerous; on the other hand in sewage, the number of micro-organisms present as bacilli vastly exceeds the number present in the spore form.

It should be noted that the samples were in no sense "picked" ones, but comprised 25 samples, received in ordinary course, which were consecutively examined for the above purposes. By the "ordinary" curve is, of course, meant the curve with the results obtained by carrying out the test in the customary manner. The "spore" curve was obtained by heating a parallel series of cultures to 80° C. for 10 minutes, so as to destroy all microbes not present in the form of spores.

The diagram shows in the most graphic manner that the bacteria, present in spore-form in sewage and effluents and capable of yielding positive results with the neutral red broth and indol tests, are far too few in number to lessen the value of these tests or to influence materially the question of standards.

Comparative bacteriology is an interesting and instructive subject, and has an important bearing on the present inquiry. It is, therefore, not out of place to point out that, whereas as regards the indol, neutral red broth and B. coli tests, sewage usually gives a positive result with $\frac{1}{100000}$ c.c., some drinking waters yield a negative result with the bacterial contents of 100 c.c.

The standard suggested in connection with these tests as regards sewage effluents, namely, a negative result with $\frac{1}{1000}$ c.c. (to qualify for discharge into non-drinking water streams) can therefore hardly be considered exacting.

SEWAGE

DIAGRAM showing the results as regards the neutral red broth (a) "ordinary" & (b) "spore" curves; & the Indol (a) "ordinary" & (b) "spore" curves of the bacteriological examination of 25 samples of sewage & effluents. [It is to be noted in each case that the "spore" curve runs at a much lower level than the "ordinary" curve and never encroaches on the line indicating the standard provisionally adopted.]

S = Sewages. E = Effluents. Horizontal black lines = suggested standards for the neutral red broth, Indol & B Coli tests, i.e., above or below 1000 per c.c.
N.B. The light tinted columns refer to the "ordinary" curve and the darker tinted columns represent the "spore" curve.

●—●—● = Number of B. coli per c.c.

Weller & Graham Ltd Litho, London.

APPENDIX VII.

Showing as regards Klein's B. enteritidis sporogenes test and the virulence of the typically changed milk cultures, the result of the bacteriological examination of samples of sewage and effluents obtained from various sources.

It has been pointed out in previous reports that the value of the B. enteritidis sporogenes test, *as a test*, does not necessarily depend on complete acceptance of the hypothesis that the microbe in question is causally related to certain cases of acute diarrhœa occurring in human beings, nor even on proof of pathogenic effect as regards rodents.* The test, *as a test*, derives its value from the fact that it enables the bacteriologist to draw a wide distinction between substances on the one hand to be thought of as highly objectionable, and on the other as of relatively harmless origin. For more than four years I have applied this test to the bacteriological examination of soils, soil "washings," waters of diverse sort, sewage and sewage effluents; and the results of these prolonged researches have been placed on record in a series of reports made to responsible bodies. It seems, therefore, unnecessary to discuss here a fact which, in my opinion, has long since been satisfactorily established namely, that the B. enteritidis sporogenes test is one of the most useful bacteriological tests which we possess at the present time. Of course, in the interpretation of the results obtained, the exercise of some judgment may be required; but this is needed in relation to all known bacteriological tests.

There remains now for consideration the vexed question of the necessity for inoculating animals with the whey of milk cultures showing the "enteritidis change."

In dealing with drinking waters, especially those not made the subject of routine examination, the advisability of inoculating animals with the whey of changed milk cultures is undoubted.

But, although a negative result obtained under these circumstances might weaken, it would not destroy belief in the presence of objectionable contamination. This, for the reason that the "enteritidis change," whether accompanied or unaccompanied by virulence of the culture, is not met with in relation to cultivations made from pure waters and, on the contrary, the characteristic reaction is always to be obtained in the case of waters polluted to any appreciable extent with matters of animal outcome. Nevertheless, when drinking waters are under examination, the inoculation of animals is to be recommended.

But, in dealing with sewage and effluents, the case is widely different. Here the liquids are known to be of comparatively recent intestinal outcome; to be always potentially dangerous to human beings; to contain the spores of B. enteritidis sporogenes in abundance, and to produce in anaërobic milk cultures for spores the characteristic change ("enteritidis change") associated with the presence of this pathogenic anaerobe, the whey of which typically changed cultures being commonly virulent to rodents. It is true that the "enteritidis change curve" may run at a higher level than the "curve of virulence;" that is, that the last milk culture (highest dilution) yielding the "enteritidis change" in a series of dilutions may be non-virulent, and virulence only be found in the next milk culture lower down in the scale of dilutions and therefore containing more of the liquid under examination. But Klein's "enteritidis change" in anaerobic milk cultures for spores is always, in my experience, of "pathological significance" in the case of sewage and effluents; and I do not regard as of vital importance the occasional lack of parallelism between the "enteritidis change curve" and the "curve of virulence." The actual facts are these, namely, that the higher the "enteritidis change curve" (i.e., positive result in higher dilutions as shown

* For convenience, the term virulence is used to indicate the death of the rodent within 48 hours of the inoculation. When the rodent, although affected by the inoculation, survived for 48 hours, the term pathogenic is applied to this condition. But this distinction is obviously arbitrary.

by length of column in the diagram) the more impure will the sample be found to be when judged by other biological tests of proved value and also the greater will be the "pathological significance" of the sample; inasmuch as if the milk culture yielding positive results be inoculated into rodents, the "curve of virulence" obtained from the results of the inoculation of rodents is likely to be a high one and to be approximate to, if not run parallel with, the "enteritidis change curve." The above remarks, be it noted, apply to domestic sewage or to mixed sewage when the admixture of trade refuse is not in such amount as to alter seriously the biological attributes of ordinary sewage. It is not contended that in exceptional cases, or even occasionally, animal inoculation experiments are not important, but only that this procedure is not necessary in ordinary routine work with sewage and sewage effluents. It must needs be remembered that for each sample at least four milk cultures are made and that in the course of a year hundreds of samples are examined.

With the object of showing how far these contentions are borne out by the results of actual experiment, 25 samples of sewage and effluents were tested as regards the "enteritidis change curve" and the "curve of virulence." The "enteritidis change curve" was obtained by inoculating a series of milk tubes severally ·1, ·01, ·001, ·0001 c.c. in the case of sewage; and 1, ·1, ·01, ·001 c.c. in the case of effluents. The milk tubes were after inoculation heated to 80° C. for 10 minutes, then placed under anaerobic conditions and incubated at 37° C. The results as regards the "enteritidis change" were noted on the 2nd day (*see* columns in diagram).

The "curve of virulence" was obtained by inoculating subcutaneously rodents with 2 c.c. of the whey from the typically changed milk cultures (dotted line in diagram). These results are shown in the appended diagram. It is specially to be noted that the samples were consecutively examined for the above purpose, and they were in no way *picked* ones.

The diagram explains itself, but here the actual results obtained may be briefly noted as follows :—

In 96 per cent. of the cases, either a virulent or a pathogenic effect was produced by using for inoculation purposes whey from the culture containing the smallest amount of the sample (highest dilution) yielding the "enteritidis change" in milk cultures.

In 92 per cent. of the cases, death occurred within 48 hours, either when using the highest dilution cultures yielding positive result or a culture lower in the scale of dilutions.

In 60 per cent. of the cases, the "enteritidis change" and the "curve of virulence" were identical.

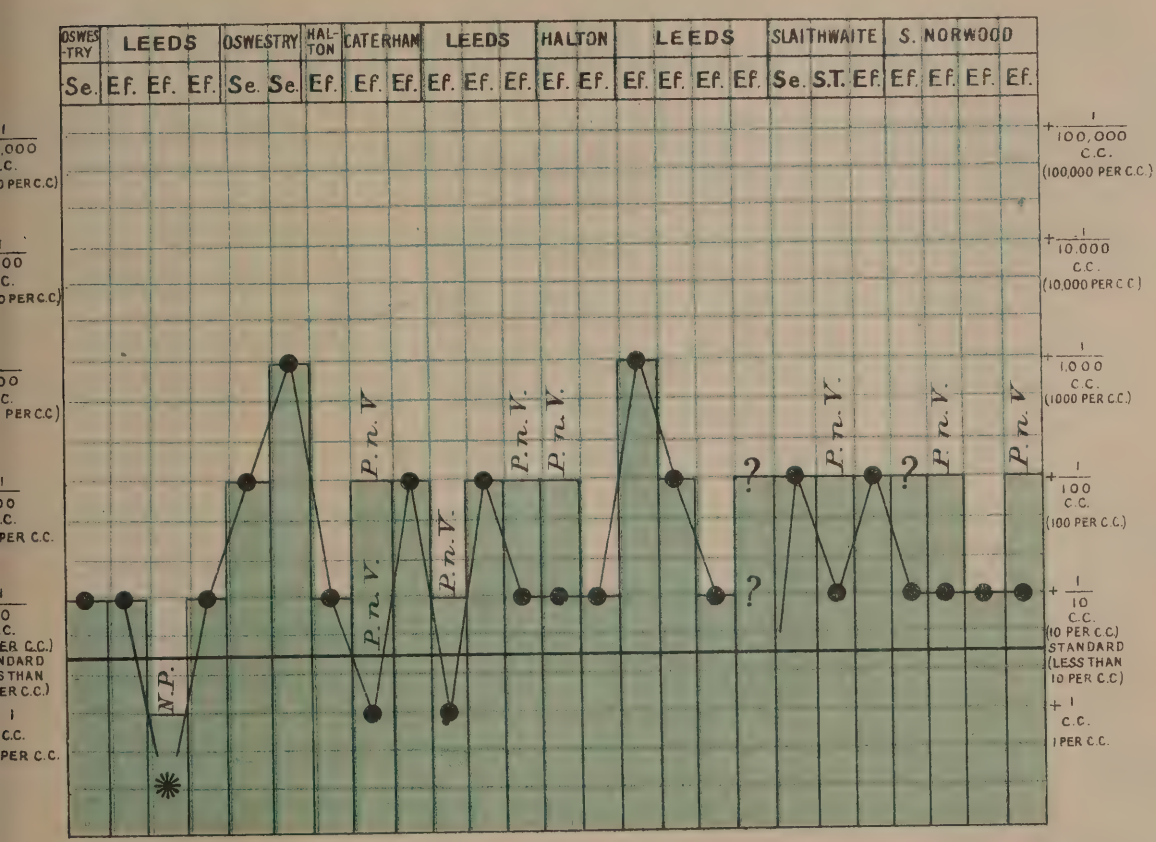
These results do not lend countenance to the view that the habitual inoculation of rodents in routine work is either necessary or wholly justifiable

SEWAGE

DIAGRAM showing as regards (1) Klein's enteritidis change in anaerobic milk cultures for sporing bacteria (B enteritidis sporogenes test) & (2) the virulence of the typically changed milk cultures the results of the bacteriological examination of samples of sewage & effluents obtained from various sources. The Oswestry, Leeds, Halton, Caterham & Slaithwaite samples represent bacterial processes of sewage treatment & the South Norwood samples, land treatment.

Se = Sewage; Ef = Effluent; S.T. = Septic Tank.

The samples were not in any way "picked" ones but represent 25 samples consecutively examined for the above purpose



In 96% of the cases either a virulent or else a pathogenic effect was produced by using for inoculation purposes the smallest amount of the sample (highest dilution) yielding the "enteritidis" change in milk culture. In 92% of the cases death occurred within 48 hours, either when using the highest dilution culture, or else a culture lower in the scale of dilutions. In 60% of the cases the "enteritidis change curve" and the curve of virulence were identical.

Represents the "enteritidis change in anaerobic milk cultures (B. enteritidis sporogenes test).

Represents the virulence of the resulting cultures. Death of rodents within 48 hours (death usually supervened within 24 hours) after injection subcutaneously of 2 c.c. of culture showing the "enteritidis change".

The "1 c.c. culture" did not kill the rodent, but judging from the other results, if a "10 c.c. culture" had been available it probably would have proved virulent.

?? The rodents did not die within 48 hours but suffered from "floating belly" & ulceration of the abdominal wall.

N.P. = Non-pathogenic. P.n.V. = Pathogenic not virulent (i.e. a pathogenic effect was produced but not death within 48 hours).

Weller & Graham Ltd. Litho. London.

ROYAL COMMISSION ON SEWAGE DISPOSAL.

SUPPLEMENTARY VOLUMES PRESENTED WITH THE FOURTH REPORT

OF

THE COMMISSIONERS

APPOINTED IN 1898

TO INQUIRE AND REPORT WHAT METHODS OF

TREATING AND DISPOSING OF SEWAGE

(INCLUDING ANY LIQUID FROM ANY FACTORY OR MANUFACTURING PROCESS)

MAY PROPERLY BE ADOPTED.

VOLUME IV.

REPORTS TO THE COMMISSION BY DR. MCGOWAN, DR. HOUSTON, AND MR. KERSHAW ON LAND-TREATMENT OF SEWAGE.

PART IV.—ENGINEERING AND PRACTICAL REPORT BY MR. G. B. KERSHAW.

Presented to both Houses of Parliament by Command of His Majesty.

LONDON:
PRINTED FOR HIS MAJESTY'S STATIONERY OFFICE,
BY WYMAN AND SONS, LIMITED, FETTER LANE, E.C.

And to be purchased, either directly or through any Bookseller, from
EYRE AND SPOTTISWOODE, EAST HARDING STREET, FLEET STREET, E.C.; and
32, ABINGDON STREET, WESTMINSTER, S.W.; or
OLIVER AND BOYD, EDINBURGH; or
E. PONSONBY, 116, GRAFTON STREET, DUBLIN.

1904.

[Cd. 1886—III.]

Presented by

Purchased

October 1908

REPORTS

TO THE

ROYAL COMMISSION ON SEWAGE DISPOSAL

ON

LAND TREATMENT OF SEWAGE.

PART IV.

ENGINEERING AND PRACTICAL REPORT

BY

MR. G. B. KERSHAW.

NOTE.—These Reports to the Commission on Land Treatment of Sewage are published in four parts, viz. :—

Part I.—General Report by Dr. G. McGowan, Dr. A. C. Houston, and Mr. G. B. Kershaw.

Part II.—Chemical Report by Dr. G. McGowan.

Part III.—Bacteriological Report by Dr. A. C. Houston.

Part IV.—Engineering and Practical Report by Mr. G. B. Kershaw.

EXTRACT FROM THE FOURTH REPORT OF THE ROYAL COMMISSION ON SEWAGE DISPOSAL. (1904. Cd. 1883).

28th December 1903.

"We have considered it desirable to publish, at this stage, the results and information which have been obtained by our own officers in regard to land treatment of sewage and methods of analysis, but we shall defer reporting on these matters until our investigations, which are now in progress, in regard to other methods of sewage treatment, are completed." (Paragraph 117, page xliii.)

PART IV.

ENGINEERING AND PRACTICAL REPORT

By G. B. KERSHAW.

6225 (iv). 1500—Wt. 26170—9 04. Wy. & S. A

CONTENTS.

		PAGE
1.	Aldershot Camp Sewage Farm	3
2.	Altrincham Sewage Farm	22
3	Croydon (Beddington) Sewage Farm	31
4.	Cambridge Sewage Farm	42
5.	Leicester Sewage Farm	51
6.	Nottingham Sewage Farm	65
7	Rugby Sewage Farm	76
8.	S. Norwood Sewage Farm	85
9.	Luton Sewage Farm	97
10.	Worsley Sewage Farm	101
11.	Hemsworth Sewage Farm	106
12.	Derby County Asylum Sewage Farm	110
13.	Sandhurst Sewage Farm Lindfield Sewage Farm Andover (Dr. Poore's System) Sewage Farm	113

APPENDICES.

Appendix A.	Notes on air, sewage, and effluent temperatures	115
,, B.	Method of taking (i.) 24 hours' sewage samples and (ii.) soil and subsoil samples	120
,, C.	Supplementary Notes on sewerage systems, storm overflows, settling tanks, underdrains and carriers	122

ALDERSHOT CAMP SEWAGE FARM.

1. Situation of farm :—Ash Vale—close to camps.
2. Total acreage of farm :—138·5 acres.
3. Total irrigable area :—120·5 acres.
4. Average area irrigated at one time :—About 40 acres.
5. Population draining to farm :—20,000.
6. Population per acre irrigated :—166.
7. Gallons of sewage per head per day :—50.
8. Dry weather flow of sewage per 24 hours :—1,000,000 gallons.
9. Gallons of sewage (exclusive of storm water) treated per acre per 24 hours :—24,900 = $(\frac{1,000,000}{40})$.
10. Gallons of sewage treated per acre per 24 hours, on the assumption that each acre of irrigable area is under sewage all the time (this for purposes of comparison) :—$(\frac{1,000,000}{120\ 5})$ = 8,300 gallons.
11. Characters of the sewage :—Purely domestic.
12. Method of treatment :—Screening, settling tanks, and land filtration.
13. General characters of the soil and subsoil :—Sand.
14. Separate or combined sewerage system :—Separate.
15. The final effluent is discharged into :—River Blackwater.
16. Number of years farm in operation before 1900 :—36 years.

ALDERSHOT CAMP SEWAGE FARM REPORT.

SUMMARY OF CONTENTS.

DESCRIPTION OF FARM.

Addendum A. Notes on Samples :—
Table I. Showing all samples drawn at the Aldershot Camp sewage farm, together with time of drawing, rainfall, temperatures, description of samples, etc.
Table II. Giving area of plots from which effluents were drawn, and the time those plots had been under sewage, etc.
Table III. Corresponding effluents.
Table IV. Comparative samples.
Table V. Sewage samples.
Additional Notes on Samples.
Addendum B. Plans and Diagrams referred to in Report :—
I. Plan of farm showing under-drainage.
II. Plans referring to river samples, and section of Bagshot Sands.
III. Plan and sections of Stanhope Lines settling tanks.
IV. ,, ,, Wellington ,, ,, ,,
V. Detail of screening arrangements, and carrier junction blocks.
VI. Detail of main effluent outfall chamber.
VII. Diagram showing hourly variations in the sewage flow over settling tank's cill—(Stanhope Lines).
VIII. Plan referring to Northern extension of farm.
IX. Temperature and rainfall chart (first visit).
X. ,, ,, ,, (new land).
XI. Temperature, rainfall, and humidity chart (third visit).

ALDERSHOT CAMP FARM.

(Domestic Sewage.)

The soil of this farm is of a sandy nature, and the sewage, which is purely domestic, is treated by means of screening, settling tanks, and land filtration.

The soil and subsoil under irrigation belong to the Bagshot series (Lower Bagshot), the soil of the entire farm being almost pure sand originally; a little gravel occurs in the subsoil in parts (Add. B, II.). The sand is very fine, and has a tendency to "pug"*. At a depth of from 2 to 4 feet a layer of "pan" or sand cemented together with iron oxide occurs. This stratum is for all practical purposes impervious to moisture, and was at first a considerable source of trouble; it has now, however, in great measure been broken up by the process of underdraining to be alluded to presently. There is now a surface soil varying in parts from 4 inches to 12 inches in depth, produced entirely by means of sewaging and ploughing in sludge incorporated with farmyard manure.

This farm has been in operation 36 years (since 1864). The land is not liable to floods. Up to the year 1880 the sewage was satisfactorily disposed of. From 1880 to 1894 it is stated to have been mismanaged. Since then it has been well managed, and is now in good condition.

The average dry-weather flow is about 1,000,000 gallons per 24 hours.

The population varies somewhat, being larger in the summer. About 20,000 would be a fair average for the whole year.

The water consumption per head is large. W.c.'s are used throughout the camp; there are no privies.

The sewage treated on the farm is derived solely from the camps.

The streets sewered are without exception sand and gravel.

The sewerage scheme throughout the camps is almost entirely on the separate system, roof and surface water passing off by means of open concrete surface channels carried round the various blocks of buildings and discharging into a watercourse named Smallshott Bottom, which skirts the farm and runs into the river Blackwater a short distance below the effluent outlet. It should be here stated that the nature and position of the military buildings render the separate system much easier of design than would be the case in any ordinary town of the same size where the rain water from the back-yards and half the roofs usually drains to the foul water sewers (even in most so-called separate systems). In the camps the street gullies are connected to the separate system, consequently in heavy rainfalls the sewage flow delivered on the farm is not materially interfered with, the volume on one occasion (30th June 1901) during a rain of ·75 inch in 4 hours only reaching a rate of flow for 3 hours of 1,500,000 gallons per 24 hours, or a 50 per cent increase.

It is necessary to keep the fact of this general exclusion of surface storm water from the sewers carefully in mind, as it has an important bearing on the working of the farm and renders it in a manner exceptional. For it is generally recognised that one of the chief drawbacks to admitting rainfall in any quantity to the foul water sewers, is the sudden changes of volume which are so troublesome to deal with at the Outfall Works. These sudden increases in flow, too, may take place during the night and early morning, when the workmen are absent, and there can be little doubt that they largely increase the chance of over sewaging parts of the farm and of sewage escaping insufficiently treated.

The average annual rainfall at Aldershot is 22 inches. The entire volume of the sewage gravitates to, and is distributed over the farm by gravitation.

The present sewerage system appears to be in good condition, and the subsoil leakage to the sewers in wet weather is clearly not great.

* By "pug" is meant a tightening of the surface sand and consequent obstruction to filtration.

Four main outfall sewers convey the sewage to the settling tanks on the farm, viz., the Stanhope Lines sewer, the Marlborough Lines sewers (two), and the Wellington Lines sewer.

The Marlborough Lines outfall consists of two lines of sewers, a 15-inch and a 12-inch, both being laid at a gradient of 1 in 700, and having a combined capacity when running full of 246·6 c.f.m.* Both of these outfalls formerly discharged separately into the Old Marlborough Lines tank; during recent alterations however (1900-1901) these two sewers have been merged into one on reaching the farm and deliver into the New Marlborough Lines tanks lately constructed on a lower portion of the farm.

The Stanhope Lines outfall is a 15-inch pipe sewer with a gradient of 1 in 400 and a capacity when running full of 210 c.f.m. The outfall delivers into the Stanhope tanks situated about 100 yards to the north of the farm premises.

The Wellington Lines sewer is the high level outfall and consists of a 12-inch pipe sewer, passing under the Basingstoke Canal by an inverted syphon just before entering the farm, and delivering into the Wellington tanks about 120 yards to the S.E. of the farm buildings. The sewage from the Wellington Lines takes about 2½ hours to reach the farm, that from the Stanhope and Marlborough Lines, under an hour. The average distances travelled by the sewage from the above lines are 1½ miles and ¾ miles respectively.

Consequently the sewage arrives on the farm in a very fresh condition—an important matter so far as efficient screening is concerned, as the fæces and paper, etc., have not become disintegrated, and are therefore much more easily screened.

There are three sets of settling tanks in use, all being worked on the continuous system, each pair of tanks being provided with a fixed bar screen or grid through which the sewage passes prior to entering the tank. These screens are formed of ½-inch galvanised iron bars, ½-inch to ¾-inch apart set at an angle of about 45° to the flow of the sewage. They are cleaned off every hour or so (Add. B, V.). About two wheelbarrow loads of screenings per tank per day are produced and deposited on the sludge beds.

With regard to the sewage from the Stanhope Lines, it may be here mentioned that it contains a good deal of sand, and therefore before being screened it passes through a deep grit or detritus chamber, the object being to deposit as much as possible of the mineral matter. This chamber requires cleaning out on the average about once in six weeks, from 5 to 8 tons being removed, according to the volume and nature of the sewage.

With the exception of the above-mentioned grit chamber the sewage is treated on precisely similar lines at each set of tanks. On passing through the screen the sewage flows into the settling tanks.

The average dry-weather flow received from the camps is, as already stated, about 1,000,000 gallons per 24 hours, about one-third of this quantity being treated at each set of tanks. This volume of sewage, with an average population throughout the year of 20,000, gives the high average of 50 gallons per head of sewage.

The Stanhope tanks are in duplicate, constructed of concrete and brick, and cement rendered; the full length of each tank to the end of the cill is 64 feet by 12 feet wide by 1 foot 6 inches deep (average depth) (Add. B, III.).

The tanks are used singly, one resting empty whilst the other one is working; when the sewage has been running into one tank for a period varying from a fortnight to three weeks, according to circumstances, the sewage is diverted into the other tank by means of sluices, whilst the former one is emptied and the sludge drawn off; the empty tank being washed, brushed down, and left perfectly clean. The sludge on being drawn off flows by gravitation along the sludge conduits to the sludge beds, where it is mixed with farmyard manure and straw, and after drying sufficiently is carted off to the land where required and ploughed in.

---

* Cubic feet per minute.

From 20 to 30 tons of wet sludge are produced at each emptying of the tanks combined, the quantity varying somewhat according to the rainfall, etc.

The Stanhope tanks have a capacity of about 6,500 gallons each. Each set of tanks, *i.e.*, the Stanhope, Wellington, and Marlborough, deal with about one-third of the total daily sewage flow, viz., about 333,300 gallons. The small amount of sludge produced from the tanks may be accounted for by the fact that nearly all the road detritus, which in most cases forms a considerable proportion of ordinary sewage sludge, does not enter the foul water sewers, but what escapes from the road gullies goes off by the separate system.

The Wellington tanks are practically similar in design to the Stanhope, with the exception that the overflow cill is straight instead of being curved. Their dimensions are:—length, 70 feet; width, 10 feet; average depth, 1 foot 8 inches; and capacity, about 7,000 gallons each tank; or a slightly greater capacity than the Stanhope (Add. B, IV.).

The old Marlborough tanks consisted of four adjacent tanks, their sizes being:—two tanks, 60 feet by 15 feet 6 inches by 2 feet 2 inches (average depth); and two tanks, one 22 feet 4 inches by 28 feet 9 inches by 2 feet 2 inches (average depth); and another, 22 feet 4 inches by 29 feet 6 inches by 2 feet 2 inches (average depth)—their combined capacity being about 22,000 gallons. They were designed some years ago, and the floors had become very rough and uneven, causing considerable inconvenience and delay in cleaning out; they have now been abolished and other tanks constructed on a new site on similar lines to the Stanhope tanks. Their dimensions are 80 feet by 12 feet by 3 feet (average depth); they are in duplicate, and each tank has a capacity of about 18,000 gallons.

Thus, the total combined capacity of the three sets of tanks when working is about 32,000 gallons, which would allow the sewage an average stay in the tanks of three-quarters of an hour approximately for settlement, which is not long (Add. B, VII.).

After passing over the tank cill the tank effluent flows along the main carriers which are laid along the highest sides of the plots to be sewaged, both pipe, earthen plough-formed carriers, and ½-pipe stoneware carriers being employed. Where overflows occur on the main carrier for the purpose of distributing the tank effluent over the land, a special four-way junction block is provided (Add. B, V.), and by inserting a sheet iron or wooden stopper in the grooves the sewage can be diverted either way as desired into the contour grips or secondary carriers, which are cut at varying distances, but usually from 50 or 60 feet apart. These contour grips or channels run out before the other side of the field or plot is reached, thus preventing the sewage from running off untreated.

The contour grips are diverted from the true contour line sufficiently to give the required fall; the grips thus have the effect of distributing the sewage equally, and, as far as it is possible, in the form of a thin stream over the land.

All the land intended to be cropped is manured every year with sludge. The whole of the farm with the exception of one field has now (10/1901) received a dressing of chalk at the rate of about 20 tons per acre.

The gross area of the farm is 138·5 acres, of which the net area available for irrigation at present is about 120·5 acres. This area of 120·5 acres deals with 1,000,000 gallons per 24 hours throughout the year. With a population of 20,000 this gives 166 persons per acre of irrigable area, or 8,300 gallons per acre. As about one-third of the irrigable area is sewaged at one time, this gives 24,900 gallons of sewage treated per acre per 24 hours. The surface of the farm has a very slight slope to the east towards the river Blackwater, and consequently it has been a matter of great difficulty to carry out the underdrainage system so as to give sufficient fall or "draw" to the drains.

In 1900 an extension was made to the northern portion of the farm, about 12½ acres of uncultivated sandy heath land and scrub being added to the farm, the whole area of which has been systematically underdrained and about six acres levelled, sown with Italian rye-grass and sewaged.

The work of levelling, etc., is carried on by the farm hands under supervision as time permits. At the present time (10/1901) nearly all the new enclosed land has been levelled and finished off.

In winter during rainfall there is some subsoil water, but as a rule when the tank effluent is taken off a plot the underdrains run dry.

The underdrainage system is brought out to one effluent chamber at the lowest part of the farm. The land is underdrained throughout with 3-inch ordinary agricultural butt tiles, laid both herringbone and parallel, at an average depth of 3 feet 3 inches (the fall obtainable not allowing them a greater depth). The distance between these feeder drains varies according to circumstances, but it is generally 12 yards. The filling above the underdrains is the same soil as that taken out of the trench, the top soil being put in first and then the remainder. These feeder drains are connected up to 4-inch, 6-inch, 9-inch, 12-inch, and finally to 15-inch stoneware socketted master drains by which the effluent is conveyed to the effluent chamber and thence through a ditch into the river Blackwater. The underdrains have air escapes or ventilators provided with gratings above the surface of the ground to avoid any air-locking during storms, also for purposes of inspection. The farm is divided into plots of sizes varying from about 2 to 13 acres.

A brief description of the method at the Camp farm of working new land to be prepared for sewage may be interesting. The land is chalked, ploughed, harrowed, and rolled, all slack places being filled in and the ground thoroughly levelled ; contour grips are cut and the tank effluent let into the contours from the main carrier through sluices. The contour grips on filling, gradually overflow in a thin stream over the land until reaching the next grip, when the sewage is cut off and applied to the next succeeding grip, the same operation taking place.

After the land has been well sewaged the water is taken off and the land left for a few days to "set" or consolidate ; this is very necessary, as deep ploughing is resorted to in the first instance to break up the ground, and otherwise crevices and holes would be apt to be left under the surface of the ground. The land is then rolled again, sown with rye-grass seed and left until the young plants are sufficiently strong to admit of irrigation (the roots of rye-grass lying close to the surface, this is necessary on a loose, sandy soil) ; it is then sewaged for some days, dried and rolled again to further consolidate the soil. After this, it is sewaged intermittently, for from four to eight days, day and night, with rests of about a week, until about ten days or a fortnight before the crop is ready to cut, when the water is taken off, the field dried, and when sufficiently firm to admit of carting, the crop is gathered, and irrigation recommenced. Approximately about 35 to 40 acres of land (old and new land) are under sewage at one time, and the sewage is usually applied for from 6 to 10 days, continuously, both day and night. The rye-grass produces, on an average, a crop every four weeks or so.

A common practice, especially in time of rainy weather, is to sewage the bottom portion of a plot first ; next, when that particular portion has received a sufficient dose, the sewage is turned on to the next preceding portion, and so on, until the whole of the plot has been sewaged.

The object of this is to enable the bottom plot to act as a reserve to catch any washings or excess that there may be from the land above it. After a period varying from two to three years, according to local circumstances, the rye-grass becomes patchy and irregular, water grass begins to appear, and the sewage flows in channels instead of in a thin sheet, when it becomes necessary to break up the ground again and re-sow it ; advantage is usually taken during this operation to level up the land. It is noticeable that the bottom portion of a field usually requires breaking up and re-sowing first, owing to its receiving any surplus sewage there may be.

Where irrigated, rye-grass should be of a uniform dark green colour, and any higher portions not receiving sewage may be observed by their yellow colour. Cabbages and mangolds are grown on ridges to avoid the lower leaves becoming saturated with sewage ; after singling the mangolds, the broken down ridges are made up with a small ridging plough

All the effluents are brought by 9-inch, 12-inch; and 15-inch pipes to one open effluent chamber (Add. B, VI.) lined with white glazed tiles, access to which is provided by steps for the purpose of taking samples.

The flow of effluent varies considerably according to the temperature. In very hot weather the effluent is often only one-half its normal flow, the

remainder being absorbed or evaporated. The normal dry-weather flow is about two-thirds of the ordinary dry-weather flow of sewage, or about 600,000 to 700,000 gallons per 24 hours which shows one gallon out of three as being absorbed or evaporated; the quality of the effluent does not appear to vary much either in summer or winter.

The river Blackwater, into which the effluent finally passes, is a small, muddy, sluggish stream.

The ratio of effluent to river water is about 1 to 6 approximately. The normal volume of the river is increased considerably by any rainfall.

The main crop grown on the farm is Italian rye-grass, together with cabbages and mangold wurtzel; about 2 roods of osiers are grown, and on the upper portion of the farm, near the buildings, market garden produce, such as rhubarb; rye-grass, however, with mangold wurtzels and cabbages, constitute the staple crop. All the mangolds are used on the farm, some of the cabbages are sold and some used for the dairy cows. The rye-grass is nearly all consumed on the farm by the cows. The root crops appear to thrive well and are in a clean condition; in common with the rye-grass they are not sewaged for some weeks before they are full grown. The rye-grass produces four to six mowings per annum, the bulk of it being used on the premises for the dairy cattle, some supplied for the use of Government horses, part sold, and part made into hay.

The utilisation of crops from a sewage farm is a serious item, particularly so where the main crop is rye-grass. In the neighbourhood of large towns, where dairy cows are kept, it can be disposed of to regular customers, but frequently a large amount of local prejudice and sentiment against it exists.

A herd of dairy cattle is kept at this particular farm, and by this means the rye-grass is regularly disposed of, together with roots, and hay made from the rye-grass, there being no necessity to rely entirely upon outside consumers. There are two brick cow-houses, each holding 24 cows, well ventilated and drained. The cows are never allowed to graze on the farm, being entirely stall fed; the cow-houses, dairy, and all the appliances are modern, and the butter and milk appear to have a good sale in the camps. Water is laid on to all the buildings.

There is no objectionable smell noticeable on the farm in connection with the distribution of the sewage except in removing and carting the sludge, but this is in no degree worse than that which would occur in leading manure on any ordinary farm.

The cost of treating the Camp sewage is about £1 18s. 4d. per million gallons.

One of the principal difficulties formerly experienced in the working of the farm was that of obtaining farm labourers in the immediate vicinity of a camp. There was also a lack of suitably built cottages, now provided close to the farm.

Another difficulty was the delay experienced in obtaining the carrying out of necessary improvements. The number of men employed on the farm varies considerably, but is usually from 20 to 30, working under the direction of the farm bailiff, superintended by Colonel Jones.

Notes on Temperature, Rainfall, etc.

The mean daily maximum temperature for the first visit (10th March to 3rd April 1900) to this farm was 9·3° C. (48·8° F.), the mean daily minimum being – 1·4° C. (29·5° F.). The mean daily rainfall for the same period was ·058 inch. Rain fell on 10 days out of 25; on four days the rainfall averaged ·30 inch. Snow fell on two days.

During the visit to the new land the rainfall was very slight, the daily mean for 14 days (24th May to 6th June 1900) being ·017 inch; the highest rainfall was ·09 inch on 31st May. The mean daily maximum was high, being 20·8° C. (69·5° F.), the average minimum reading being 6·6° C. (44° F.).

At the third visit to the farm exceedingly heavy rainfall occurred on 30th June and 2nd July, ·80 inch being registered on the former of these days and ·64 inch on the latter. The mean daily rainfall for the visit (19th June to 23rd July 1901) was ·06 inch. The mean daily maximum was high, being 25·6° C. (78·1° F.); the mean daily minimum was 9·5° C. (49·1° F.), or a mean difference between the maxima and minima of 16·1° C. (29° F.). The humidity averaged 71·2. (See Add. B, IX., X., and XI.)

TABLE I.

DOMESTIC SEWAGE.

TABLE shewing all Samples drawn at Aldershot Camp Farm.

Number of Sample.	Date of drawing Sample.	Time of day.	Rainfall day previous to drawing Sample.	Rainfall day of drawing Sample.	Air Temperature time of drawing Sample.	Temperature of Sample.	Maximum Temperature during the 24 hours.	Minimum Temperature during the 24 hours.	Humidity (9 a.m.)	Dissolved Oxygen in Sample.	Brief description of Sample.	REMARKS.
	1900:		Inches.	Inches.	°C. °F.	°C. °F.	°C. °F.	°C. °F.				
48	12 March	11 a.m.	·01	·00	*—	8·3 (47)	7·2 (45)	0·00 (32)	—	—	Crude sewage.	Dissolved oxygen, humidity, and air temperature were not taken until a later stage.
49	12 „	3.15 p.m.	·01	·00	—	6·6 (44)	7·2 (45)	0·00 (32)	—	—	Effluent.	
50	14 „	11 a.m.	·00	·00	—	7·2 (45)	11·6 (53)	3·8 (39)	—	—	Screened and settled sewage.	*Mean daily maximum temperature, 9·3 °C. (48·8°) F.
51	14 „	3.15 p.m.	·00 (snow)†	·00 (snow)	—	6·6 (44)	11·6 (53)	3·8 (39)	—	—	Effluent.	Mean daily minimum temperature, – 1·3 °C. (29·5°) F.
52	19 „	11.15 a.m.	(·30)	(·14)	—	6·6 (44)	10· (50)	– 1·1 (30)	—	—	„	Mean daily rainfall ·058 in.
53	19 „	11.30 „	(·30)	(·14)	—	7·2 (45)	10· (50)	– 1·1 (30)	—	—	„	*For the period 10th March 1900 to 3rd April 1900.
54	21 „	1 p.m.	·00	·29	—	7·2 (45)	6·6 (44)	3·3 (38)	—	—	Screened and settled sewage.	
55	21 „	4 „	·00 (snow)	·29 (snow)	—	6·1 (43)	6·6 (44)	3·3 (38)	—	—	Effluent.	†Samples which may have been affected by rainfall or snow are underlined.
56	27 „	12.15 „	(·05)	(·31)	—	7·7 (46)	7·7 (46)	– 1·8 (29)	—	—	„	
57	27 „	12.30 „	(·05)	(·31)	—	5·5 (42)	7·7 (46)	– 1·8 (29)	—	—	River water.	
58	27 „	12.45 „	(·05)	(·31)	—	5·5 (42)	7·7 (46)	– 1·8 (29)	—	—	River water and effluent	
59	27 „	1.15 „	(·05)	(·31)	—	5·5 (42)	7·7 (46)	– 1·8 (29)	—	—	„ „	
60	2 April	12 (noon)	·00	·04	—	7·2 (45)	12·7 (55)	– 2·2 (28)	—	—	Subsoil water.	
81	28 May	11.45 a.m.	·00	·00	19·4 (67)	14·4 (58)	22·2 (72)	5·5 (42)	—	—	Screened and settled sewage.	*Mean daily maximum temperature, 20·8 °C. (69·5) °F.
82	28 „	3 p.m.	·00	·00	18·8 (66)	11·1 (52)	22·2 (72)	5·5 (42)	—	—	Effluent.	Mean daily minimum temperature, 6·6 °C. (44°) F.
83	29 „	3.15 „	·00	·00	17·2 (63)	11·6 (53)	20· (68)	6·1 (43)	—	—	„	Mean daily rainfall ·017 in.
84	30 „	3.15 „	·00	·01	17·2 (63)	11·6 (53)	17·2 (63)	7·7 (46)	—	—	„	
85	31 „	2.45 „	·01	·09	10·5 (51)	11·6 (53)	12·7 (55)	11·1 (52)	—	—	„	
86	5 June	12.45 „	·00	·00	14·4 (58)	15·5 (60)	23·8 (75)	3·8 (39)	—	—	Screened and settled sewage.	
87	5 „	3	·00	·00	14·4 (58)	12·2 (54)	23·8 (75)	3·8 (39)	—	—	Effluent.	

ALDERSHOT CAMP FARM.—TABLE I.

DOMESTIC SEWAGE (continued).

Number of Sample.	Date of drawing Sample.	Time of day.	Rainfall day previous to drawing Sample.	Rainfall day of drawing Sample.	Air Temperature time of drawing Sample.	Temperature of Sample.	Maximum Temperature during the 24 hours.	Minimum Temperature during the 24 hours.	Humidity (9 a.m.)	Dissolved Oxygen in Sample.	Brief description of Sample.	REMARKS.
			Inches.	Inches.	°C. °F.	°C. °F.	°C. °F.	°C. °F.				
	1900:											
88	6 June	3.15 p.m.	·00	·00	16·1 (61)	12·7 (55)	27·2 (81)	10· (50)	—	—	Effluent.	*For the period 24th May 1900 to 6th June 1900.
89	6 „	2.30 „	·00	·00	16·6 (62)	12·2 (54)	27·2 (-1)	10· (50)	—	—	„	
90	7 „	3.15 „	·00	·00	14·4 (58)	17·2 (63)	—	—	—	—	„	
	1901:											
245	1 April	2.0 „	heavy rain.	·00	10·5 (51)	9·4 (49)	—	—	—	—	Screened and settled sewage.	
246	1 „	2.15 „	„	·00	10·5 (51)	5·5 (42)	—	—	—	—	Effluent.	
247	1 „	3.0 „	„	·00	10· (50)	5·5 (42)	—	—	—	—	„	
302	19 June	11.5 a.m.	·00	·05	18·8 (66)	20· (68)	23·8 (75)	10·5 (51)	94*	—	Screened and settled sewage.	*Saturation = 100
303	19 „	11.30 „	·00	·05	17·7 (64)	20· (68)	23·8 (75)	10·5 (51)	94	—	„ „ „	
304	19 „	12.30 p.m.	·00	·05	21·1 (70)	12·2 (54)	23·8 (75)	10·5 (51)	94	—	Effluent.	
305	19 „	12.45 „	·00	·05	21·1 (70)	12·2 (54)	23·8 (75)	19·5 (51)	94	—		
306	24 „	11.30 a.m.	·00	·00	19·4 (67)	17·7 (64)	23·3 (74)	4·4 (40)	61	—	Screened and settled sewage.	
307	24 „	12.45 p.m.	·00	·00	20· (68)	12·2 (54)	23·3 (74)	4·4 (40)	61	—	Effluent.	
308	25 „	11.45 a.m.	·00	·00	20· (68)	13·3 (56)	23·3 (74)	11·1 (52)	69	—	„	*Mean daily maximum temperature, 25·5 °C., 78·1° F. Mean daily minimum temperature, 9·5 °C., 49·1° F. Mean daily rainfall, ·06 inch. Mean daily humidity, 71·2.
309	25 „	12.15 p.m.	·00	·00	18·8 (66)	12·7 (55)	23·3 (74)	11·1 (52)	69	—	„	
310	27 „	10.45 a.m.	·00	·00	21·1 (70)	12·7 (55)	23·8 (75)	3·8 (39)	63	—	„	
310a	2 July	12 (noon)	·10	·64	16·1 (60)	17·7 (64)	22·2 (72)	13·3 (56)	98	—	Crude sewage.	
311	2 „	12.45 p.m.	·10	·64	16·1 (61)	16·1 (61)	22·2 (72)	13·3 (56)	98	—	Street washings.	
312	2 „	1 „	·10	·64	16·1 (61)	12·7 (55)	22·2 (72)	13·3 (56)	98	—	Effluent.	
313	3 „	11 a.m.	·64	·00	20· (68)	12·7 (55)	22·7 (73)	9·4 (49)	61	—	„	*For the period 19th June to 24th July 1901.
314	3 „	11.45 a.m.	·64	·00	21·1 (70)	15·5 (60)	22·7 (73)	9·4 (49)	61	—	Street washings.	
314a	4 „	11.10 a.m.	·00	·00	22·7 (73)	12·7 (55)	27·2 (81)	12·7 (55)	74	—	Effluent.	
314b	4 „	11.30 „	·00	·00	22·2 (72)	13·3 (56)	27·2 (81)	12·7 (55)	74	—	„	
314c	4 „	11.45 „	·00	·00	22·2 (72)	12·7 (55)	27·2 (81)	12·7 (55)	74	—	„	
314d	5 „	10.30 „	·00	·00	23·3 (74)	12·7 (55)	22·7 (73)	13·3 (56)	65	—	„	
314e	5 „	11 „	·00	·00	23·8 (75)	13·3 (56)	22·7 (73)	13·3 (56)	65	—	„	

314f	5 July	11.25 a.m.	·00	·00	24·4	(76)	12·7	(55)	22·7	(73)	13·3	(56)	65	—	Effluent.	*A sample of red worms marked No. 316a taken from river below effluent outlet was sent to Professor Boyce.
314g	8 ,,	11.5 ,,	·00	·00	20·	(68)	18·8	(66)	24·4	(76)	9·4	(49)	66	—	Crude sewage.	
315	8 ,,	11.30 ,,	·00	·00	19·4	(67)	20·	(68)	24·4	(76)	9·4	(49)	66	5 c.c.	River water.	
316*	8 ,,	12 (noon)	·00	·00	20·	(68)	20·	(68)	24·4	(76)	9·4	(49)	66	3 c.c.	River water and effluent.	
314h	8 ,,	1 p.m.	·00	·00	21·1	(70)	12·7	(55)	24·4	(76)	9·4	(49)	66	5 c.c.	Effluent.	
317	9 ,,	11 a.m.	·00	·00	20·	(68)	13·8	(57)	27·7	(82)	7·2	(45)	67	—	,,	
317a	9 ,,	11.45 ,,	·00	·00	21·1	(70)	13·8	(57)	27·7	(82)	7·2	(45)	67	—	,,	
318a	10 ,,	10.30 ,,	·00	·00	24·4	(76)	14·4	(58)	27·7	(82)	8·3	(47)	66	—	,,	
318	10 ,,	10.49 ,,	·00	·00	24·4	(76)	14·4	(58)	27·7	(82)	8·3	(47)	66	—	,,	
318b	11 ,,	11.5 ,,	·00	·00	26·6	(80)	20·	(68)	31·1	(87)	8·8	(48)	68	—	Crude sewage.	
318c	11 ,,	11.30 ,,	·00	·00	27·2	(81)	14·4	(58)	31·1	(87)	8·8	(48)	68	—	Effluent.	
318d	11 ,,	11.45 ,,	·00	·00	27·2	(81)	14·4	(58)	31·1	(87)	8·8	(48)	68	—	,,	
318e	12 ,,	10.55 ,,	·00	·15	28·3	(83)	15·	(59)	28·8	(84)	13·8	(57)	72	—	,,	
318f	12 ,,	11.25 ,,	·00	·15	28·8	(84)	15·	(59)	28·8	(84)	13·8	(57)	72	—	,,	
319a	15 ,,	10.30 ,,	·00	·00	21·1	(70)	15·	(59)	23·8	(75)	6·6	(44)	73	—	,,	
319	15 ,,	10.15 ,,	·00	·00	21·6	(71)	15·	(59)	23·8	(75)	6·6	(44)	73	—	,,	
319b	16 ,,	10.35 ,,	·00	·00	26·6	(80)	14·4	(58)	27·7	(82)	5·5	(42)	64	—	Crude sewage.	
319c	16 ,,	11.30 ,,	·00	·00	27·2	(81)	15·	(59)	27·7	(82)	5·5	(42)	64	—	Effluent.	
320	17 ,,	10.45 ,,	·00	·00	26·6	(80)	25·5	(78)	31·1	(87)	5·5	(42)	63	—	Sewage from carrier, screened and settled.	
320a	17 ,,	11.45 ,,	·00	·00	27·2	(81)	15·	(59)	31·1	(87)	5·5	(42)	63	—	Effluent.	
321	17 ,,	12.30 p.m.	·00	·00	27·2	(81)	15·	(59)	31·1	(87)	5·5	(42)	63	—	,,	
322a	18 ,,	11.15 a.m.	·00	·00	31.1	(87)	15·	(59)	32·7	(91)	9·4	(49)	69	—	,,	
322	18 ,,	11.35 ,,	·00	·00	29·4	(85)	15·	(59)	32·7	(91)	9·4	(49)	69	—	,,	
322b	19 ,,	12 (noon)	·00	·00	32·2	(90)	15·	(59)	33·3	(92)	10·5	(51)	60	—	,,	
322c	19 ,,	12.15 p.m.	·00	·00	32·2	(90)	15·	(59)	33·3	(92)	10·5	(51)	60	—	,,	
323	22 ,,	11 a.m.	·00	·03	20·	(68)	15·	(59)	22·7	(73)	10·5	(51)	60	—	,,	
323a	22 ,,	11.30 ,,	·00	·03	20·5	(69)	20·	(68)	22·7	(73)	10·5	(51)	60	—	Crude sewage.	
323b	22 ,,	4.30 p.m.	·00	·03	20·	(68)	15·	(59)	22·7	(73)	10·5	(51)	60	—	Effluent.	
324a	23 ,,	11 a.m.	·03	-20	18·3	(65)	15·	(59)	21·6	(71)	11·1	(52)	90	—	,,	
324	23 ,,	11.15 ,,	·03	·20	18·8	(66)	15·	(59)	21·6	(71)	11·1	(52)	90	—	,,	
325a	24 ,,	9.45 ,,	·20	·10	18·8	(66)	20·	(68)	—		—		95	—	Crude sewage.	
325	24 ,,	10 ,,	·20	·10	18·8	(66)	16·1	(61)	—		—		95	—	Effluent.	
326	24 ,,	10.35 ,,	·20	·10	18·8	(66)	16·1	(61)	—		—		95	—	River water.	*A sample of supernatant mud from river surface below effluent outlet marked No. 328 was sent to Mr. McGowan.
327*	24 ,,	11 ,,	·20	·10	18·8	(66)	16·1	(61)	—		—		95	—	River water and effluent	
389	14 October	12.15 p.m.	·00	·00	13·8	(57)	13·8	(57)	15·	(59)	7·7	(46)	—	—	Crude sewage.	
390	14 ,,	12.30 ,,	·00	·00	12·2	(54)	12·2	(54)	15·	(59)	7·7	(46)	—	—	General effluent.†	†By general effluent is meant a mixture of two or more finally treated effluents on leaving the farm.
391	14 ,,	1 ,,	·00	·00	13·8	(57)	12·2	(54)	15·	(59)	7·7	(46)	—	—	Effluent.	
392	14 ,,	1.30 ,,	·00	·00	13·3	(56)	11·6	(53)	15·	(59)	7·7	(46)	—	—	,,	
393	15 ,,	10.45 a.m.	·00	·08	14·4	(58)	13·3	(56)	15·5	(60)	2·7	(37)	—	—	Crude sewage.	
394	15 ,,	11.30 ,,	·00	·08	15·	(59)	12·7	(55)	15·5	(60)	2·7	(37)	—	—	Effluent.	
395	15 ,,	12 (noon)	·00	·08	13·8	(57)	12·7	(55)	15·5	(60)	2·7	(37)	—	—	,,	*Mean daily maximum temperature, 15·3 °C., 59·6° F.
396	15 ,,	11.10 a.m.	·00	·08	14·4	(58)	12·2	(54)	15·5	(60)	2·7	(37)	—	—	General effluent.	

ALDERSHOT CAMP FARM.—TABLE I.

DOMESTIC SEWAGE (continued).

Number of Sample.	Date of drawing Sample.	Time of day.	Rainfall day previous to drawing Sample.	Rainfall day of drawing Sample.	Air Temperature time of drawing Sample.		Temperature of Sample.		Maximum Temperature during the 24 hours.		Minimum Temperature during the 24 hours.		Humidity (9 a.m.)	Dissolved Oxygen in Sample.	Brief description of Sample.	REMARKS.
			Inches.	Inches.	°C.	°F.	°C.	°F.	°C.	°F.	°C.	°F.				
397	16 October -	10.30 ,, -	·08	·55	11·1	(52)	13·3	(56)	15·5	(60)	7·2	(45)	—	—	Crude sewage.	Mean daily minimum temperature, 7·7° C., 46° F. Mean daily rainfall, ·266 in.
398	16 ,, -	11 ,, -	·08	·55	11·6	(53)	12·2	(54)	15·5	(60)	7·2	(45)	—	—	General effluent.	
399	16 ,, -	11.30 ,, -	·08	·55	11·1	(52)	12·2	(54)	15·5	(60)	7·2	(45)	—	—	Effluent.	
400	16 ,, -	12 (noon) -	·08	·55	11·1	(52)	12·2	(54)	15·5	(60)	7·2	(45)	—	—	,,	*For the period 13th October to 18th October 1901.
401	17 ,, -	10 15 a.m. -	·55	·05	11·1	(52)	13·3	(56)	16·1	(61)	9·4	(49)	—	—	Screened and settled sewage.	
402	17 ,, -	10.40 ,, -	·55	·05	11·1	(52)	11·6	(53)	16·1	(61)	9·4	(49)	—	—	General effluent.	
403	17 ,, -	11.5 ,, -	·55	·05	10·5	(51)	11·6	(53)	16·1	(61)	9·4	(49)	—	—	Effluent.	
404	17 ,, -	11.20 ,, -	·55	·05	10·5	(51)	11·1	(52)	16·1	(61)	9·4	(49)	—	—	,,	
405	18 ,, -	10 ,, -	·05	·65	12·2	(54)	13·3	(56)	14·4	(58)	11·6	(53)	—	—	Screened and settled sewage.	
406	18 ,, -	10.30 ,, -	·05	·65	12·2	(54)	12.2	(54)	14·4	(58)	11·6	(53)	—	—	Effluent.	
407	18 ,, -	10.50 ,, -	·05	·65	12·2	(54)	12·2	(54)	14·4	(58)	11·6	(53)	—	—	General effluent.	
408	18 ,, -	11.20 ,, -	·05	·65	12·2	(54)	11·6	(53)	14·4	(58)	11·6	(53)	—	—	Effluent.	
	1902:															
460	28 January -	Noon Monday to 11 a.m. Tuesday.	·40	·01	-	-	-	-	-	-	-	-	—	—	24 hours' sewage sample.	Screened and settled sewage.
461	28 ,, -	12 (noon) -	·40	·01	7·2	(45)	4·4	(40)	—		—		—	—	Final effluent.	
462	29 ,, -	Noon Tuesday to 11 a.m. Wednesday.	·01	·00	-	-	-	-	-	-	-	-	—	—	24 hours' sewage sample.	,, ,, ,, ,,
463	29 ,, -	3 p.m. -	·01	·00	0·0	(32)	1·6	(35)	—		—		—	—	Final effluent.	
464	30 ,, -	Noon Wednesday to 11 a.m. Thursday.	·00	·00	-	-	-	-	-	-	-	-	—	—	24 hours' sewage sample.	,, ,, ,, ,,
465	30 ,, -	11.30 a.m. -	·00	·00	—·5	(31)	1·6	(35)	—		—		—	—	Final effluent.	

ALDERSHOT CAMP SEWAGE FARM.

TABLE II.

DOMESTIC SEWAGE.

EFFLUENTS.

Number of Sample.	Number of times treated.	Area of plot or plots sewaged.	Period sewaged previously to drawing Sample.	Nature of crops grown on plots.	REMARKS.
		Acres.	*Days.		
49	Once	5.42	* 3	Arable fallow - -	Unchalked land: *Plot sewaged continuously day and night.
51	Once	9·58 3·21	* 8	Ryegrass - - -	Unchalked land: very poor crop, laid down two years.
52	Once	4·9	* 3	Ryegrass - - -	Unchalked land: crop in good condition.
53	Once	—	—	—	General effluent.
55	Once	9·58 3·21	* 3	Ryegrass - - -	Unchalked land.
56	Once	—	—	—	General effluent.
82	Once	3·0	† 6	Young ryegrass - -	Chalked land: young ryegrass only just up. (†Land sewaged for 12 hours by day only.)
83	Once	3·0	† 7	Young ryegrass - -	- ditto - ditto -
84	Once	3·0	† 8	Young ryegrass - -	- ditto - ditto -
85	Once	3·0	† 9	Young ryegrass - -	- ditto - ditto -
87	Once	3·0	†14	Young ryegrass - -	- ditto - ditto -
88	Once	3·0	†15	Young ryegrass - -	- ditto - ditto -
89	Once	—	—	—	General effluent.
90	Once	5·08	‡ 4	Ryegrass - - -	Chalked land: ‡Sewaged night and day.
246	Once	40·0	Various Periods.	Ryegrass and arable -	Chalked land: general effluent.
247	Once	3·21	*14	Ryegrass - - -	Unchalked land.
304	Once	5·80	* 3	Ryegrass - - -	—
305	Once	10·0	* 3	Ryegrass - - -	—
307	Once	1·0	* 7	Ryegrass (cut) - -	—
308	Once	7·0	* 7	Ryegrass - - -	—
309	Once	1·0	* 8	Ryegrass (cut) - -	—
310	Once	—	—	—	General effluent.
312	Once	1·50	*15	Ryegrass (cut) - -	—
313	Once	1·50	*16	Ryegrass (cut) - -	—
314a	Once	1·50	*17	Ryegrass (cut) - -	—
314b	Once	7·0	* 3	Ryegrass - - -	—
314c	Once	3·0	* 2	Ryegrass - - -	—
314d	Once	1·50	*18	Ryegrass (cut) - -	—
314e	Once	3·0	* 3	Ryegrass - - -	—
314f	Once	3·0	* 7	Ryegrass - - -	—
314h	Once	1·50	*21	Ryegrass (cut) - -	—
317	Once	1·50	*22	Ryegrass (cut) - -	—
317a	Once	—	—	—	General effluent.
318a	Once	—	—	—	General effluent.
318	Once	1·75	*23	Ryegrass (cut) - -	—
318c	Once	—	—	—	General effluent.
318d	Once	1·75	*24	Ryegrass (cut) - -	—
318e	Once	—	-	—	General effluent.

TABLE II. (continued).

DOMESTIC SEWAGE.

EFFLUENTS.

Number of Sample.	Number of times treated.	Area of plot or plots sewaged.	Period sewaged previously to drawing sample.	Nature of crops grown on plots.	REMARKS.
318f	Once	1·75	*25	Ryegrass (cut) - -	——
319a	Once	—	—	—	General effluent.
319	Once	3·21	* 5	Ryegrass - - -	——
319c	Once	5·08	* 6	Ryegrass (cut) - -	——
320a	Once	—	—	—	General effluent.
321	Once	1·75	* 2	Ryegrass (cut) - -	——
322a	Once	—	—	—	General effluent.
322	Once	2·0	* 3	Ryegrass (cut) - -	——
322b	Once	—	—	—	General effluent.
322c	Once	3·25	* 7	Ryegrass - - -	——
323	Once	2·0	* 7	Ryegrass (cut) - -	——
323b	Once	—	—	—	General effluent.
324a	Once	—	—	—	General effluent.
324	Once	2·0	* 8	Ryegrass (cut) - -	——
325	Once	2·0	* 9	Ryegrass (cut) - -	——
390	Once	—	—	—	General effluent.
391	Once	3·0	* 7	Ryegrass - - -	Final effluent.
392	Once	4·0	* 6	Ryegrass - - -	Final effluent.
394	Once	3·0	* 8	Ryegrass - - -	Final effluent.
395	Once	4·0	* 7	Ryegrass - - -	Final effluent.
396	Once	—	—	—	General effluent.
398	Once	—	—	—	General effluent.
399	Once	3·0	* 9	Ryegrass - - -	Final effluent.
400	Once	4·0	* 8	Ryegrass - - -	Final effluent.
402	Once	—	—	—	General effluent.
403	Once	3·0	*10	Ryegrass - - -	Final effluent.
404	Once	4·0	* 9	Ryegrass - - -	Final effluent.
406	Once	3·0	*11	Ryegrass - - -	Final effluent.
407	Once	—	—	—	General effluent
408	Once	4·0	*10	Ryegrass - - -	Final effluent.
461	Once	2·0	*10	Ryegrass - - -	Final effluent.
463	Once	2·0	*11	Ryegrass - - -	Final effluent.
465	Once	2·0	*12	Ryegrass - - -	Final effluent.

ALDERSHOT CAMP FARM.

TABLE III.

DOMESTIC SEWAGE.

* Corresponding Effluents.

From Old Land.	From New Land A.	From New Land B.	REMARKS.
ample Nos. 48 and 49.	Sample Nos. 81 and 82.	Sample Nos. 306 and 307.	* *i.e.*, Effluents corresponding to crude or screened and settled sewage in each case. That is to say, that the effluent is taken some time after the sewage sample, to show as far as possible the degree of purification effected on that particular sewage.
„ „ 50 and 51.	„ „ 86 and 87.	„ „ 314g and 314h.	
„ „ 54 and 55.			
„ „ 302 and 304.			
„ „ 303 and 305.			
„ „ 314c and 314e.			

TABLE IV.

* Comparative Samples, or Samples taken from the same plots of land.

†Old Land.	‡New Land B.	§New Land A.	REMARKS.
Numbers.	Numbers.	Numbers.	
51, 55	307, 309	82, 83, 84, 85, 87, 88	* By "Comparative" samples is meant samples drawn from the same areas of land, and the effluents in brackets are comparable with each so far as the area of land sewaged is concerned.
314c, 314e	312, 313, 314a, 314d, 314h, 317	321, 322, 323, 324, 325	† By "Old" land effluents is meant those effluents from the old portion of the farm as distinct from the "new."
391, 394, 399, 403, 406	318, 318d, 318f	392, 395, 400, 404, 408	‡ New land "B." (coloured green on small plan) was brought into operation in June 1901. (See Addendum B, VIII.)
		461, 463, 465	§ New land "A" (coloured pink on small plan) was brought into operation in May 1900.

ALDERSHOT CAMP FARM.

Domestic Sewage.

Sewage Samples.

Number of Sample.	Nature of Sewage.	Source.	Time taken.	Remarks.
48	Crude sewage - - -	Wellington Lines tanks	11.0 a.m. -	Very strong, taken before being screened or entering tanks.
50	Screened and settled sewage	Stanhope " "	11.0 a.m. -	Very strong, taken after being screened and settled.
54	" " " "	" " "	1.0 p.m. -	Very strong, taken after being screened and settled.
81	" " " "	Marlborough " "	11.45 a.m.	Very strong, taken after being screened and settled, slightly alkaline.
86	" " " "	" " "	12.45 p.m.	Soapy sewage, taken after being screened and settled.
245	" " " "	" " "	2.0 p.m. -	Fairly strong, taken after being screened and settled.
802	" " " "	Stanhope " "	11.5 a.m. -	Fairly strong, taken after being screened and settled.
303	" " " "	Marlborough " "	11.30 a.m.	Very strong, taken after being screened and settled.
306	" " " "	" " "	11.30 a.m.	Strong, taken after being screened and settled, septic looking.
314g	Crude sewage - - -	" " "	11.15 a.m.	Strong, taken before being screened and settled.
318b	" " - - -	" " "	10.49 a.m.	Strong, taken before being screened and settled.
319b	" " - - -	" " "	10.35 a.m.	Fairly strong, taken before being screened and settled.
320	Screened and settled sewage	" " "	10.45 a.m.	*Not very strong, taken after being screened and settled.
323a	Crude sewage - - -	" " "	11.30 a.m.	Not very strong, taken before being screened and settled.
325a	" " - - -	" " "	9.45 a.m.	Not very strong, taken before being screened and settled.
389	" " - - -	Stanhope " "	12.15 p.m.	Strong, taken before passing through settling tank.
393	" " - - -	" " "	10.45 a.m.	Apparently stronger than 389, probably owing to time of day.
397	" " - - -	" " "	10.30 a.m.	Apparently weaker than usual owing to rainfall.
401	Screened and settled sewage	" " "	10.15 a.m.	A strong sample, possibly owing to very heavy rain scouring out the sewers.
405	" " " "	" " "	10.15 a.m.	Fairly strong.

* Taken from the carrier just before going on to the land.

24 hours sewage samples :—

Sample No. 460, 28th January 1902—from noon, Monday, 27th January to noon, Tuesday, 28th January 1902—Screened and settled sewage—heavy rain (·40 inch) in the early morning.

Sample No. 462, 29th January 1902—from noon, Tuesday, 28th January, to noon, Wednesday, 29th January 1902—Screened and settled sewage—·01 inch rainfall.

Sample No. 464, 30th January 1902—from noon, Wednesday, 28th January, to noon, Thursday, 30th January 1902—Screened and settled sewage—·00 inch rainfall.

Additional Notes on Different Samples.

Aldershot Camp Farm.

Domestic Sewage.—Winter Visit.

Sample No. 50.—Screened and settled sewage from Stanhope Lines, one mile distant, and having passed through a bar screen, with ¾-inch spaces, and settling tank.

Sample No. 52.—This effluent represents an average sample of the farm during wet weather.

Sample No. 53.—General effluent contained some sewage weed. During wet weather the sewage in consequence of the increased flow sometimes reaches portions of the land not usually irrigated, and should there be any rat or mole holes, reaches the drains imperfectly purified. In addition, any accumulation of sewage weed or sediment in the drain during a dry period is washed out in times of rainfall.

Sample No. 56.—General effluent, very dirty yellow colour, turbid, a good deal of it being caused no doubt by some of it having come off the worst parts of the farm; *i.e.*, the parts not yet drained or levelled.

Sample No. 57.—River water taken 30 yards above junction of effluent outlet; a fairly clear sample, river about normal height (about 4,000,000 gallons per 24 hours). The river appeared to be in a fairly satisfactory state. (Add B, II.)

Sample No. 58.—River water and effluent taken 30 yards below effluent outlet; the effluent, entering the river channel at right angles, appeared to be thoroughly mixed with the river water.

Sample No. 59.—River water and effluent, taken 170 yards below effluent outlet. This sample could not be taken any lower down the river owing to another brook joining the river at that point. Some cattle had apparently been in the stream between the points where Nos. 58 and 59 were drawn, some time previously to drawing the sample.

Sample No. 60.—Subsoil water drawn from a pump well near the farm, 8 feet deep (no chance of contamination from the farm); 3 feet 6 inches of water in the well at time of drawing sample, very clear and sparkling appearance. This well varies in depth according to the amount of rainfall. In July (1901) the water was 1 foot 6 inches deep.

End of Winter Visit.—Spring Visit.

Sample No. 82.—Effluent from new land (3 acres) sewaged 6 days, by day only for 12 hours (*i.e.*, 6 a.m. to 6 p.m.) Effluent smelt strongly of sewage and was of a deep orange colour. The rye-grass was newly sown, and was not up sufficiently to affect the purification appreciably. The sewage was flowing on at about the rate of 20,000 gallons per 24 hours.

The surface of the soil was not yet consolidated, being left 2 inches to 3 inches higher than the other land to allow of settlement.

In preparing the land a four-horse deep plough was employed, this leaving the soil loose immediately beneath the surface and causing the sewage in some parts to run direct to the drains.

Sample No. 83.—Some large holes letting the sewage direct to the drains. Orange-coloured effluent.

Sample No. 84.—Holes in land filled up and rammed, orange-coloured effluent.

Sample No. 85.—Yellow coloured effluent, and slight smell.

Sample No. 87.—Some holes in land started again. Land to be thoroughly rolled once the sewage has been taken off, to consolidate it.

Waterman walking about on the land under sewage stirs up the sediment; effluent orange coloured.

Sample No. 88.—Holes stopped up. Effluent not quite so deep an orange colour.

Sample No. *89.—General effluent from old land, yellow coloured, slight sediment. This would include the new land final effluent.

Sample No. 90.—Effluent from old land, 5·08 acres rye-grass, sewaged for four days; fairly clear, slight smell.

Sample No. 245.—Screened and settled sewage from Marlbro' Lines. New tanks now in use, and better sedimentation obtained thereby. Sewage strong. Sewage is strongest about 10 a.m. and 3 p.m. This sample was drawn the day following heavy rainfall.

Sample No. 246.—General effluent from about 40 acres of old land; slight sewage smell, yellowish colour, some sewage fungus. Heavy rainfall appears to disturb the soil for some time afterwards, some of the surface soil being apt to wash off in heavy storms. This general effluent had no effluent water from the new land running into it.

Sample No. 247.—Effluent from old land rye-grass, 3·21 acres sewaged 14 days; fairly clear and no smell.

Note.—Effluents subsequent to No. 247 were all drawn from land that had been chalked.

Summer Visit.—New land during this visit was sewaged continuously during the 24 hours:—

Sample No. 304.—Effluent from old land, 5·80 acres rye-grass, sewaged three days; only fairly clear, very slight smell.

Sample No. 305.—Effluent from old land, 10 acres rye-grass (*i.e.*, 11·55 plot), sewaged three days; yellowish colour, decided smell, some sewage fungus.

All general effluents subsequent to No. 82 contain the new land effluents.

Sample No. 307.—Effluent from new land B. This land appeared to be more consolidated than New land A., and not so liable to form waterways for the sewage to the drains; hay crop only just gathered off ground. Surface cut about by waggons and carts. A mere dribble of effluent running, opalescent colour.

Sample No. 308.—Effluent from old land; yellowish colour, some sewage fungus.

Sample No. 309.—Effluent from new land; deep yellow, opalescent colour. Land not set very well, and cut up by carts during hay time, etc. Moles worked during the time that the field was dry.

Sample No. 310.—General effluent; yellow colour, some finely divided sewage weed, strong sewage smell.

Sample No. 311.—Street washings and roof water taken from surface water ditch, after two days' heavy rainfall, *i.e.* probably as pure as one could expect to obtain it. At the time of drawing sample this surface water ditch was flowing at about the rate of 10,000,000 gallons per 24 hours; sample a turbid brown colour.

Sample No. 312.—Effluent from new land. Sample drawn during very heavy rainfall (·64 inch); some sewage was escaping direct over the surface of the land to the pick-up carrier at foot of plot and thence to effluent chamber. Some solids were washed on to the land; in consequence partly of the sewage being put upon the land in larger quantities than usual, to soak the land, this in combination with the rainfall producing the overflow. The worst sample drawn, being practically weak sewage.

Sample No. 313.—Effluent from new land; yellow colour; land only just recovering from the heavy rain.

Sample No. 314.—Street washings and roof water after three days' rain; turbid and apparently worse than the previous sample of street water, probably owing to a slight escape of sewage from the farm.

Sample No. 314a.—Effluent from new land. No visible short cuts of sewage to drains. Effluent still very yellow in colour. The ryegrass growing very slowly in consequence of drought, but assisted by late rains.

Sample No. 314b.—Effluent from old land; some suspended matter in effluent. Not a very clear sample.

Sample No. 314c.—Effluent from old land. Not a very clear sample, and a good deal of sediment.

Sample No. 314d.—Effluent from new land; yellow colour; land apparently in fair working order.

Sample No. 314e.—Effluent from old land; fairly clear.

Sample No. 314f.—Effluent from old land; a good deal of suspended matter.

Sample No. 314h.—Effluent from new land; yellow colour.

Sample No. 315.—River water above effluent outfall; cloudy blue colour; 5 c.c.'s dissolved oxygen. A good deal of froth and scum coming down the stream owing to rainfall.

Sample No. 316.—River water 30 yards below effluent outfall; dissolved oxygen 3 c.c.'s, cloudy blue colour; some fermentation going on in the stream.

Sample No. 317.—Effluent from new land; yellow colour; slight seaweed smell.

Sample No. 317a.—General effluent from old and new land; a clear-looking sample, very little suspended matter, slight seaweed smell. This represents, as far as could be judged, a fair sample of a "general" or "combined" effluent in dry weather.

Sample No. 318.—Effluent from new land; yellow colour; strong seaweed smell.

Sample No. 318a.—General effluent from old and new land, about same in appearance as No. 317a, but clearer if anything; slight seaweed smell.

Sample No. 318c.—General effluent fairly clear, similar to No. 318a in appearance.

Sample No. 318d.—Effluent from new land; yellow colour; a larger flow of effluent running, similar in appearance to No. 318.

Sample No. 318e.—General effluent from old and new land, similar to No. 318d in conditions and appearance, but apparently more suspended matter. Perhaps due to increased flow and therefore scouring action.

Sample No. 318f.—Effluent from new land, similar in appearance to No 318e, but slightly less suspended matter.

Sample No. 319.—Effluent from old land; a good deal of suspended matter*

Sample No. 319a.—General effluent from old and new land; a fairly clear sample, green algae showing in effluent chamber.

Sample No. 319c.—Effluent from old land; a very fairly clear sample, rye-grass just starting to grow.

Sample No. 320.—Screened and settled sewage taken from the carrier just before going on to the new land (A); rather weak.

Sample No. 320a.—General effluent from old and new land; a fairly clear sample.

Sample No. 321.—Effluent from new land B. Plot sewaged for two days, day and night continuously; very little effluent running owing to drought; deep yellow colour.

---

* During very lengthy periods of drought, the amount of effluent coming away from the farm is often diminished by as much as one-half. When a field or plot is left dry for some days and then sewaged, a good deal of matter washes from the drains at first.

PLAN OF

ALDERSHOT CAMP FARM

SHEWING

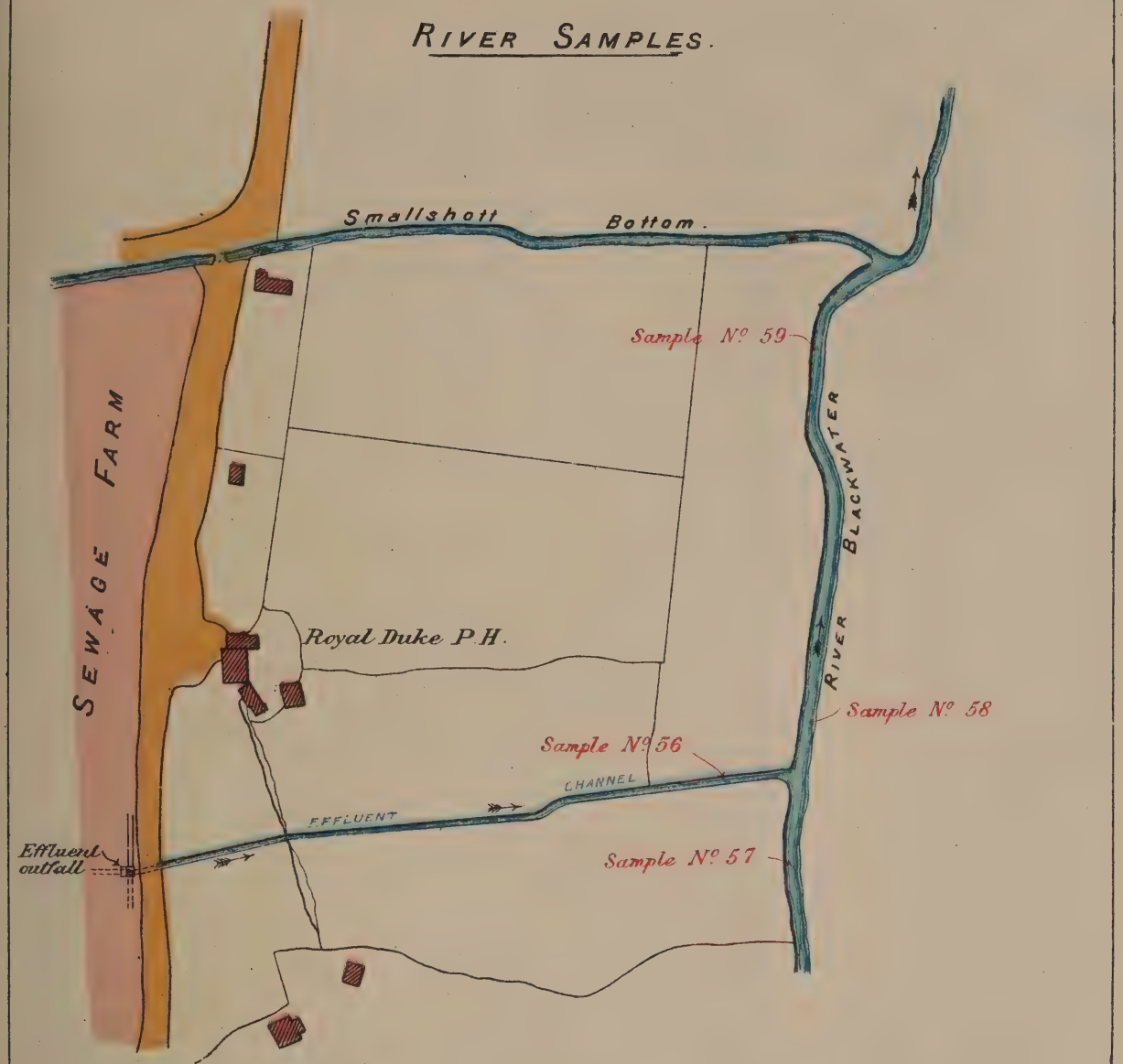
UNDERDRAINAGE SYSTEM

3311. 8. 02.

Weller & Graham Ltd Litho. London

Aldershot Camp Sewage Farm.

Scale :- 25.344 Inches to 1 Mile.



Aldershot Camp Farm.

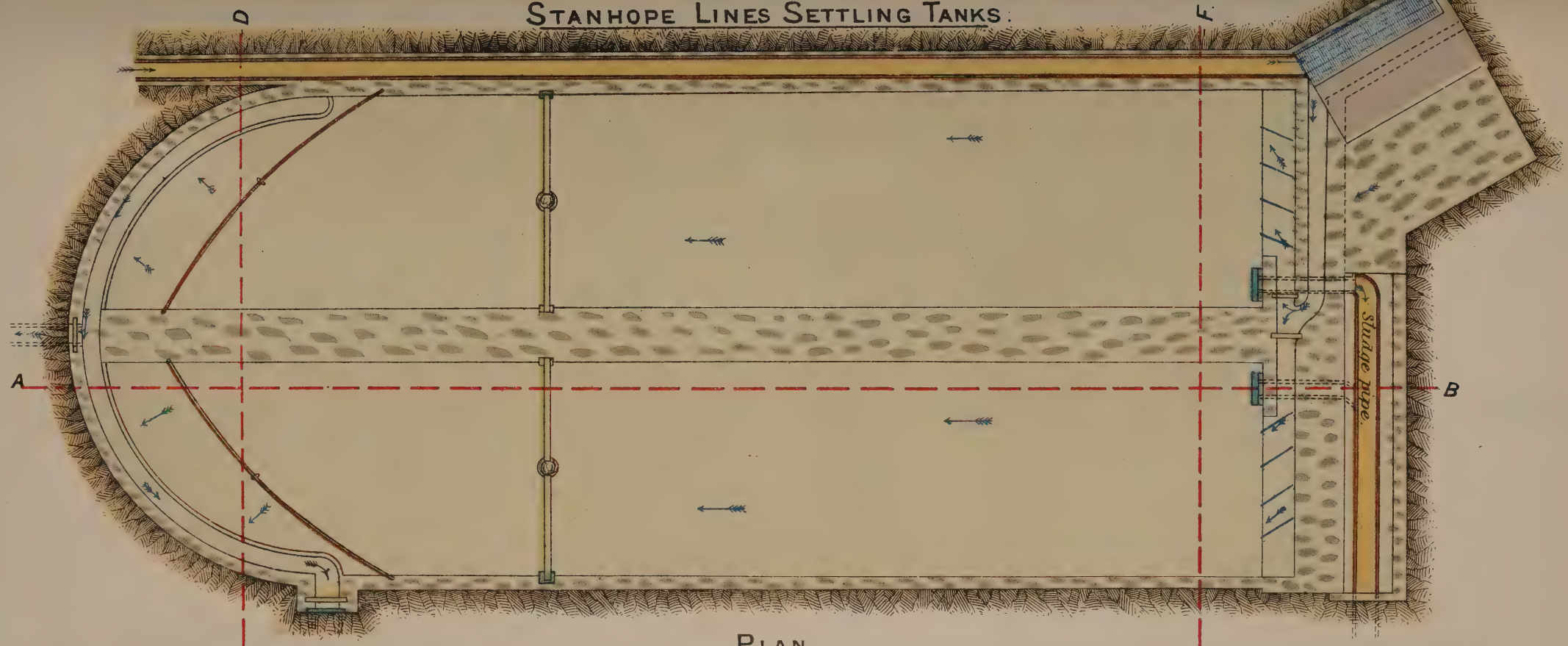
Section of Lower Bagshot Sands.

3311. 7. 1902.

Weller & Graham Ltd Litho. London.

Scale:-8 ft = 1 in.

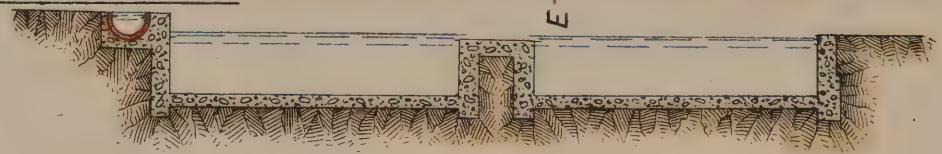
STANHOPE LINES SETTLING TANKS.



PLAN.

LONGITUDINAL SECTION A.B

SECTION ON C.D.

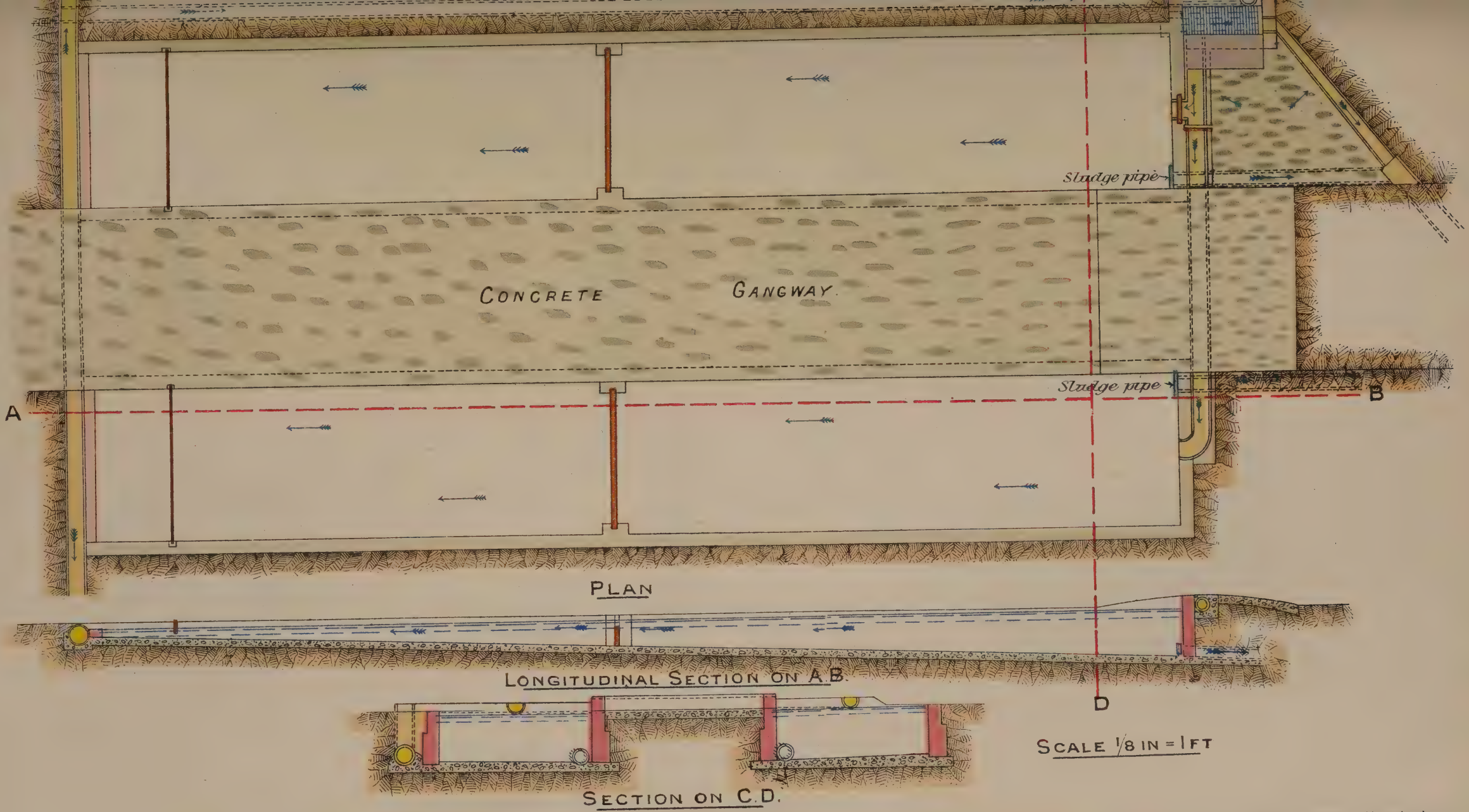


SECTION ON E.F.

3311. 7. 1902.

Weller & Graham Ltd Litho. London.

Addendum. B. III.



3311 7 1902

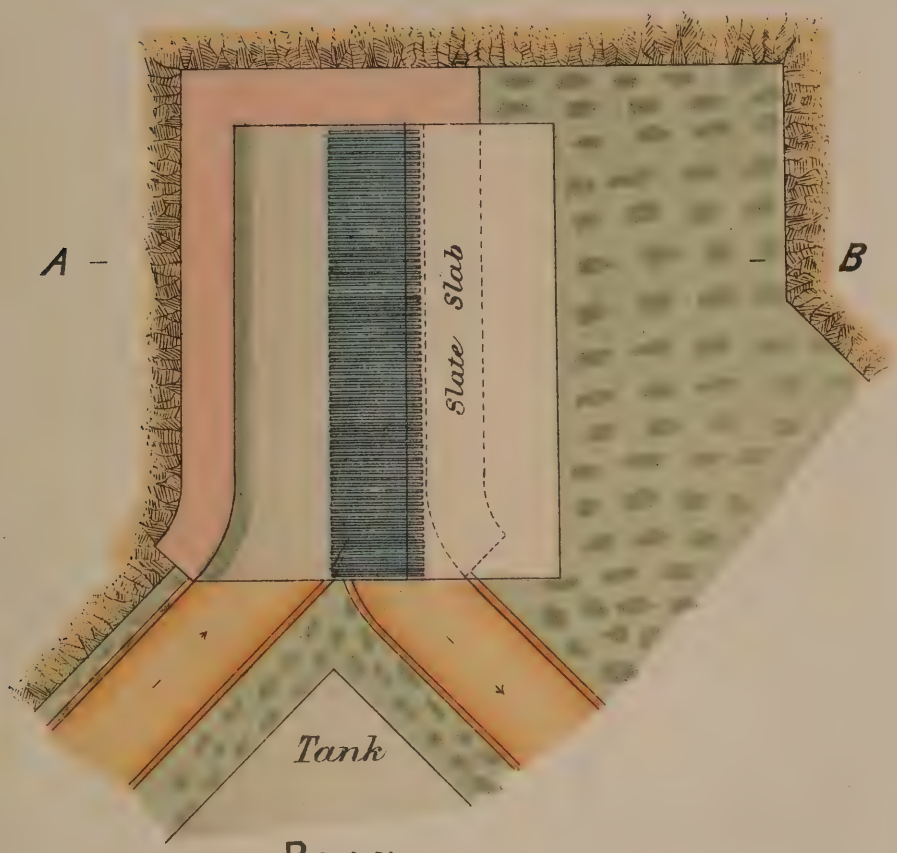
Weller & Graham Ltd Litho. London.

IV.

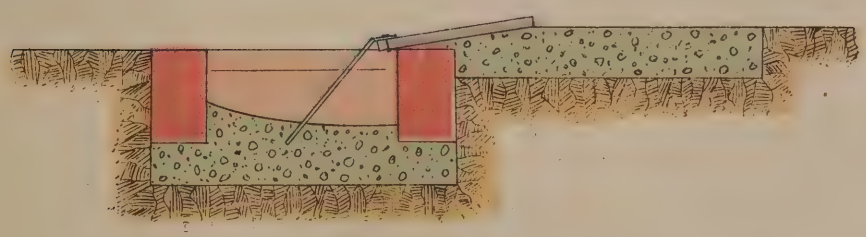
Aldershot Camp Sewage Farm.

Sewage Screen.

Scale ½ in = 1 Ft.

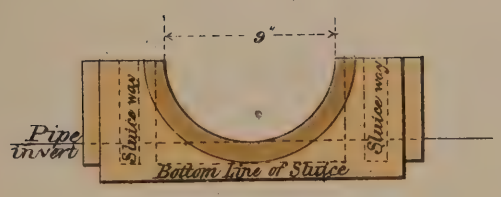


Plan.



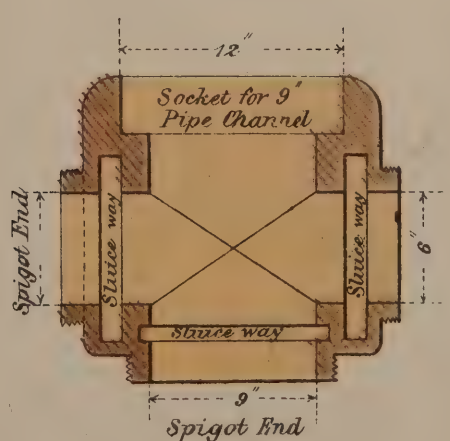
Section on A. B.

Junction Blocks.



Elevation.

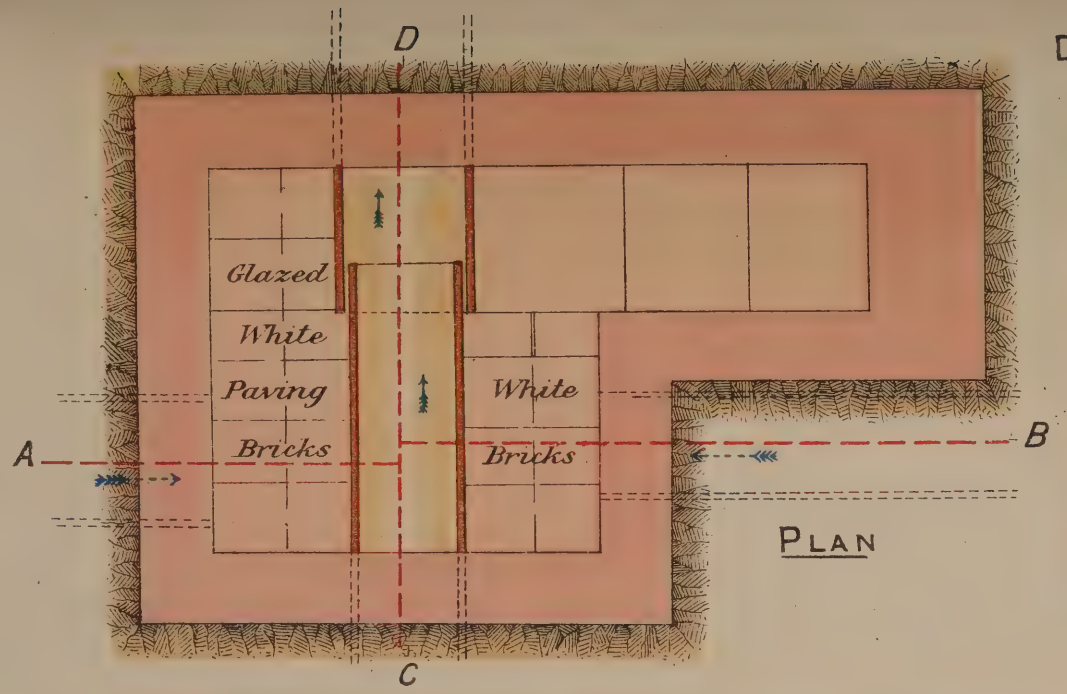
Scale 1½ ins. to a Foot.



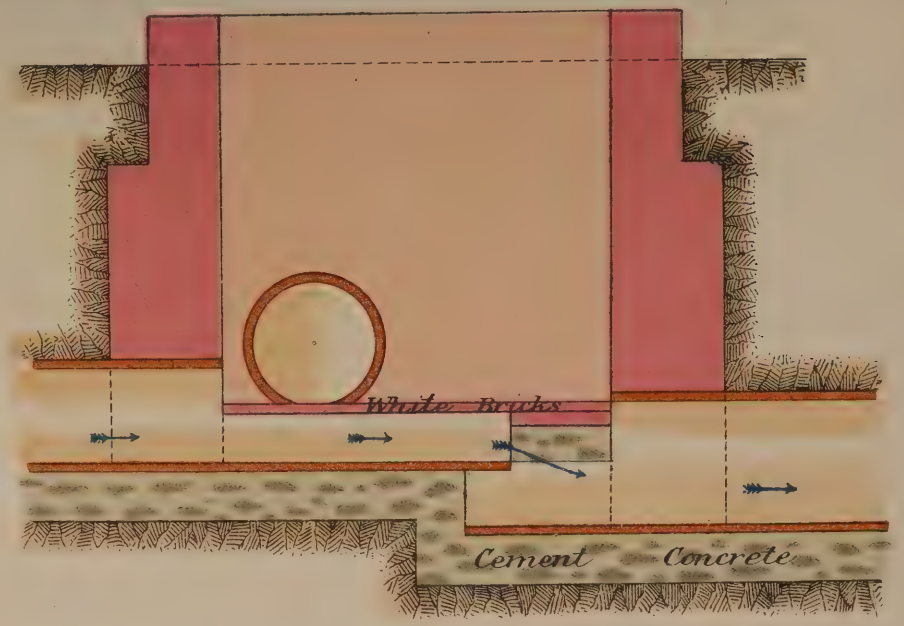
Plan.

Weller & Graham, Ltd Litho.

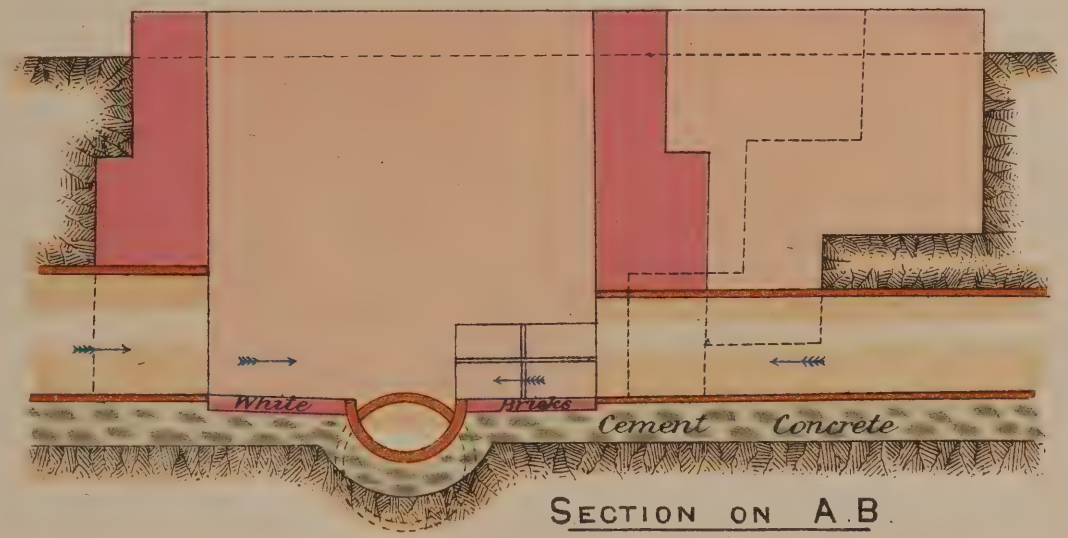
Details of Main Effluent Outfall Chamber



Plan



Section on C D



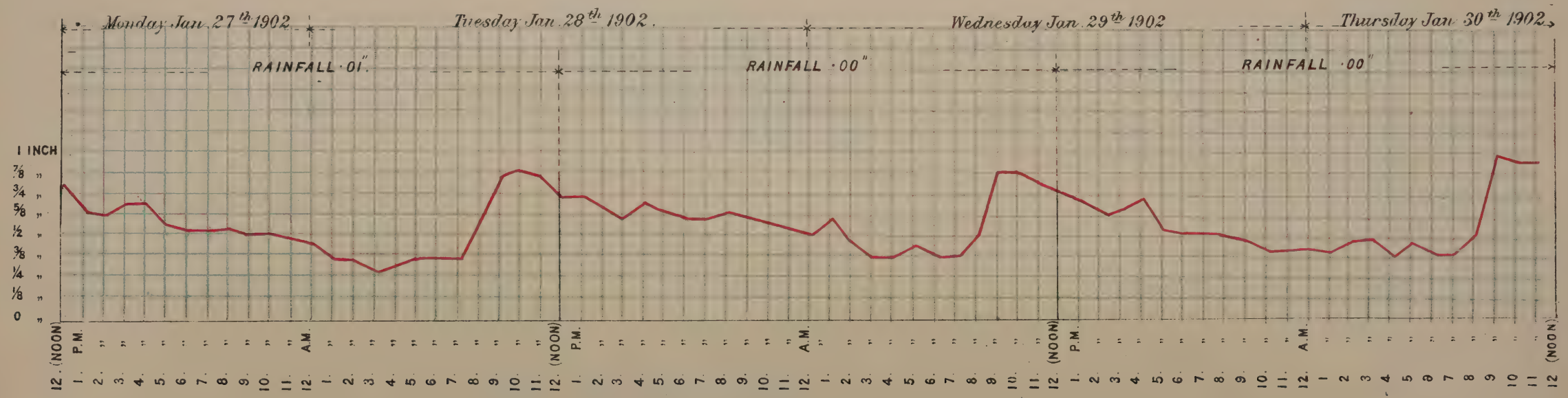
Section on A B

Scale ½ in = 1 ft.

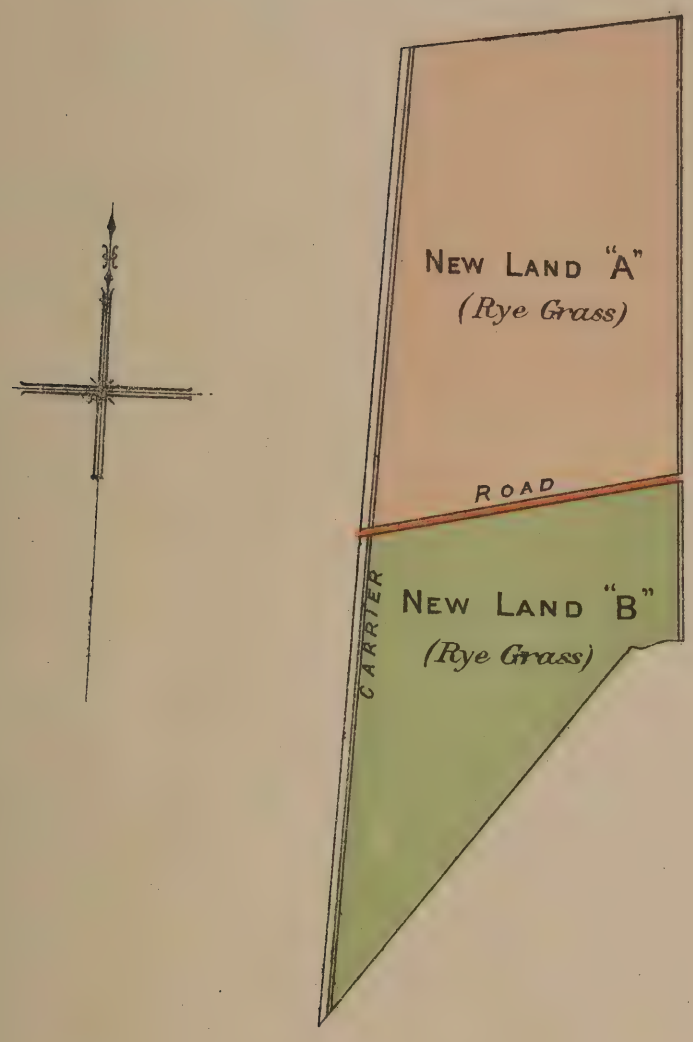
Weller & Graham Ltd Litho. London.

ALDERSHOT CAMP. (STANHOPE LINES)

Hourly Variations in the Sewage flow over settling tank cill.



ALDERSHOT CAMP SEWAGE FARM.

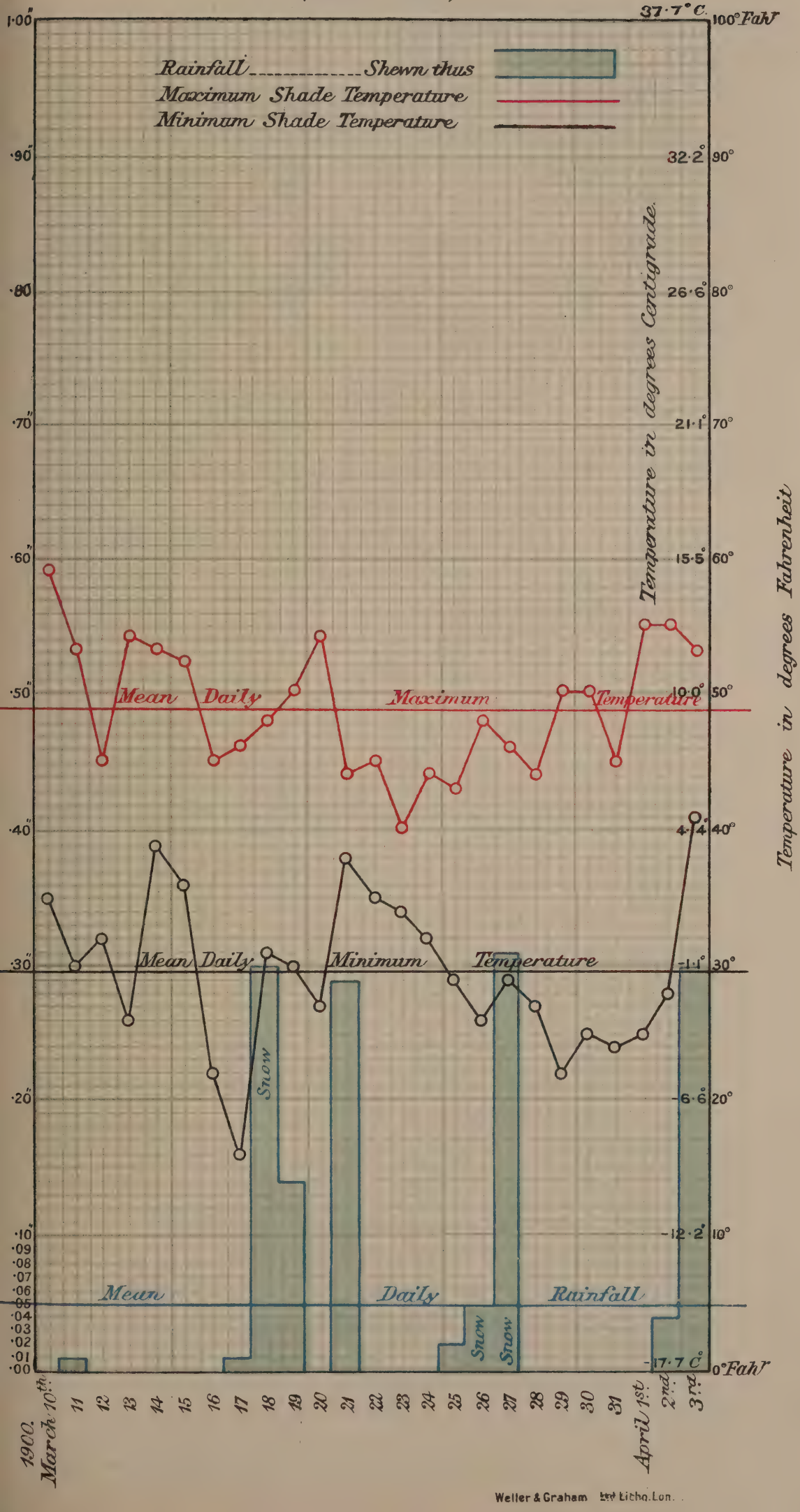


The above Plan refers to the Northern extension of the Farm referred to else where. The portion coloured Pink (referred to as New land "A") was laid out for Sewage in 1900. & was brought into operation in May 1900. The lower portion which is coloured Green (referred to as New land "B") was laid out for Sewage subsequently to New land "A" & was not brought into operation until June 1901. Briefly, "A" was sown with rye grass & Sewage put on for the first time in May 1900. After about 14 days the Sewage was taken off & the land rolled. Sewage was again put on immediately after the rolling - Subsequently, it was sewaged after each crop was cut, about the same as the Old land. The same operations took place with regard to New land "B"

Weller & Graham Ltd Litho London

ALDERSHOT CAMP SEWAGE FARM.

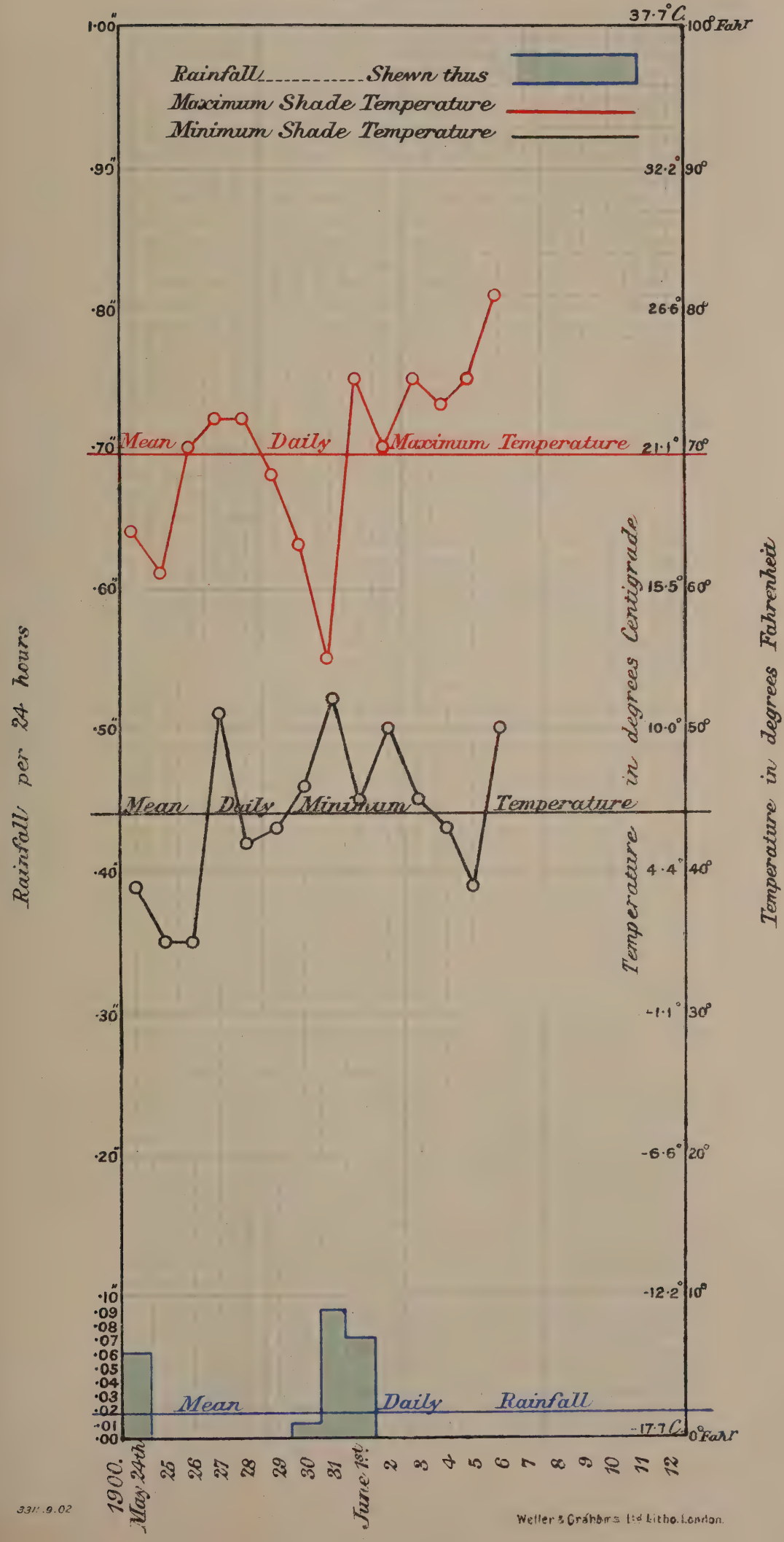
(First Visit).



Weller & Graham Ltd Litho. Lon.

ALDERSHOT CAMP SEWAGE FARM.

(New Land)



3311.9.02

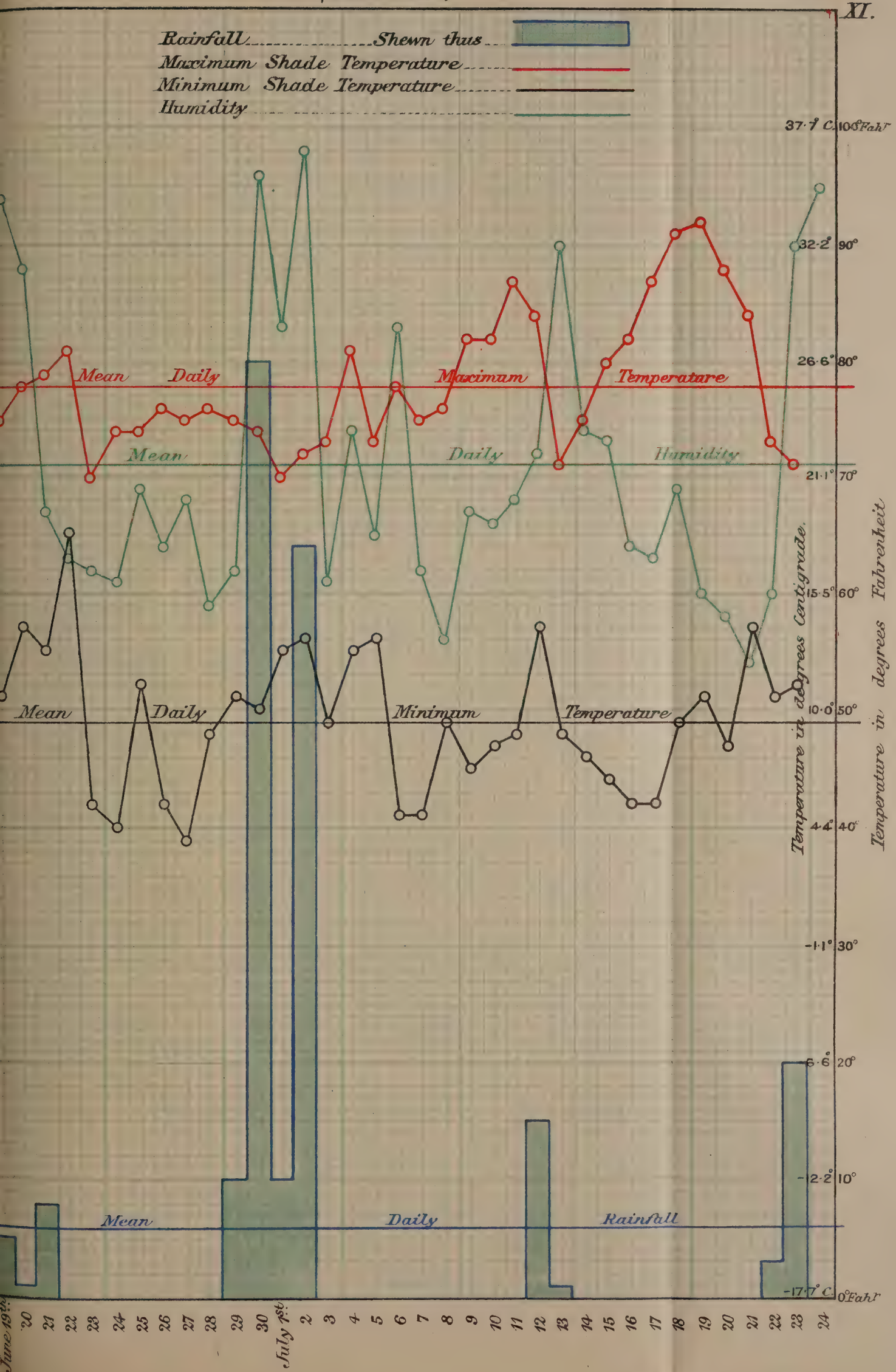
Weller & Grahams Ltd Litho. London.

ALDERSHOT CAMP SEWAGE FARM.

(Third Visit.)

Addendum B.

XI.



Waller & Graikoms. Lith. London.

Sample No. 322.—Effluent from new land B sewaged continuously for three days. Effluent a deep yellow colour; still very little running, probably due in some measure to the sewage being on a slightly increased area. A large amount of sediment in effluent

Sample No. 322a.—General effluent from old and new land; some little sediment coming down; slight smell.

Sample No. 322b.—General effluent from old and new land; similar to No. 322a. in colour, but more sediment.

Sample No. 322c.—Effluent from old land; a fairly clear sample, no perceptible smell.

Sample No. 323.—Effluent from new land B, sewaged day and night continuously; very little effluent running, and much red suspended matter; a good deal of sediment was stirred up owing to having to collect sample in very small quantities.

Sample No. 323b.—General effluent from old and new land; a good deal of suspended matter, owing no doubt to slight rainfall; slight sewage smell.

Sample No. 324.—Effluent from new land B.

Note.—A slight amount of only surface-treated sewage had entered effluent at bottom of plot; effluent a frothy, dirty colour in consequence.

Sample No. 324a.—General effluent from old and new land B only fairly clear, in all probability affected by bad effluent from new land B.

Sample No. 325.—Effluent from new land B (raining heavily during drawing of sample), a little surface-treated sewage getting in.

Sample No. 326.—River water taken 30 yards above effluent outlet; river rather high (about at the rate of 10,000,000 gallons per 24 hours); a turbid sample drawn during rain.

Sample No. 327.—River water taken 30 yards below effluent outlet; no perceptible difference between the two samples, No. 327 if anything clearer than No. 326.

Sample No. 390.—General Effluent: some suspended matter; yellowish colour; hardly such a good sample as usual.

Sample No. 391.—Final Effluent: a clear sample.

Sample No. 392.—Final Effluent: very little effluent running, top end only of plot being sewaged; slight sewage smell.

Sample No. 394.—Final Effluent: from same source as 391; clear.

Sample No. 395.—Final Effluent: from same source as 392; yellow colour; a little more effluent running.

Sample No. 396.—General Effluent: slightly less suspended matter than in No. 390.

Sample No. 398.—General Effluent: some sediment; rather dilute, owing to rain (·20 inch) rain also probably caused more sediment.

Sample No. 399.—Final Effluent: same source as 394; some sediment, due to rainfall, otherwise clear.

Sample No. 400.—Final Effluent: same source as 395; yellow colour, a good deal of sediment; a fair amount of effluent running.

Sample No. 402.—General Effluent: fairly clear; very slight sewage smell. After heavy rain.

Sample No. 403.—Final Effluent: same source as 399, clear, no smell.

Sample No. 404.—Final Effluent: same source as 400; yellow colour. After ·55 inch rainfall; sewage smell.

Sample No. 406.—Final Effluent: same source as 403; clear, no smell; ·30 inch fell during drawing of samples.

Sample No. 407.—General Effluent: fairly clear; taken during heavy rain.

Sample No. 408.—Final Effluent: same source as 404; a fair amount of effluent running and less yellow than previously; taken during heavy rain.

Sample No. 461.—Final Effluent. This effluent was undoubtedly affected by the heavy rainfall, and was dilute.

Sample No. 463.—Final Effluent. This sample contained some red flocculent matter.

Sample No. 465.—Final Effluent: some red suspended matter, otherwise a very clear sample.

24 hours sewage samples, Nos. 460, 462, and 464.—These samples were taken from the screened and settled sewage on leaving the tanks, that being the condition in which it is applied to the land.

ALTRINCHAM SEWAGE FARM.

(Altrincham Urban District Council).

---

1. Situation of farm :—Bordering on Carrington Moss, about 2 miles from Altrincham.
2. Total acreage of farm :—75·5 acres.
3. Total irrigable area :—35 acres.
4. Average area irrigated at one time :—17·5 acres.
5. Population draining to farm :—18,000.
6. Population per acre irrigated :—514.
7. Gallons of sewage per head per day :—44·4.
8. Dry weather flow of sewage per 24 hours :—800,000 gallons.
9. Gallons of sewage (exclusive of storm water) treated per acre per 24 hours :—46,000 = $\left(\frac{800,000}{17\cdot5}\right)$.
10. Gallons of sewage treated per acre per 24 hours, on the assumption that each acre of irrigable area is under sewage all the time (this for purpose of comparison) :—$\left(\frac{800,000}{35}\right)$ = 23,000 gallons.
11. Characters of the sewage :—Domestic.
12. Method of treatment :—Settling tank and land filtration.
13. General characters of the soil and subsoil :—Peaty soil lying upon sand and gravel.
14. Separate or combined sewerage system :—Combined.
15. The final effluent is discharged into :—Sinderland Brook.
16. Number of years farm in operation before 1900 :—30 years

ALTRINCHAM SEWAGE FARM REPORT.

SUMMARY OF CONTENTS.

DESCRIPTION OF FARM.

Addendum A. Notes on Samples :—

Table I. Showing all samples drawn at the Altrincham sewage farm, together with time of drawing, rainfall, temperatures, description of samples, etc.

Additional Notes on Samples.

Table II. Giving area of plots from which effluents were drawn, and the time those plots had been under sewage, etc.

Table III. Sewage samples.

Table IV. Comparative samples.

Addendum B. Plans and Diagrams referred to in Report :—

I. Plan of farm

II. Plan referring to brook samples, and section of soil and subsoil.

III. Diagrammatic plan and section of lagoon, and plan and section of main carried.

IV Diagram showing hourly variations in temperature of crude sewage.

V. Temperature and rainfall chart (first visit).

VI. Temperature, rainfall, and humidity chart (second visit)

ALTRINCHAM SEWAGE FARM.

(Altrincham Urban District Council.)

The sewage, which is domestic, is treated by means of a settling tank and land filtration.

The soil varies in places, the surface soil consisting of 8in. to 10in. of black porous soil, mixed with and lying upon a layer of decomposed peat 4in. to 7in. deep, superimposed upon fine white sand and gravel (Add. B, II.). About one-half of the farm was formerly pure bog land (Carrington Moss); the remaining half, or southern portion, of the farm is of a sandier nature. The actual peat land is not irrigated. There is a large quantity of iron in the soil, and a "pan" of some 3in. to 6in. in thickness occurs in places.

The farm has been in operation 30 years, since about 1870. It is managed by the Altrincham Urban District Council.

The average dry weather flow is 800,000 gallons per 24 hour, or 44·4 gallons per head of the population.

The present population of Altrincham served by the sewerage system is 17,500; a portion of Dunham Massey (500 persons) brings this to a total of 18,000 persons draining to the sewage farm.

The drainage area (built area) draining to the farm is about 500 acres. The population per acre of drainage area is, therefore, 36, which is small, and consequently the subsoil leakage to the sewers per head is proportionately more than would be the case in a thickly populated district.

The Altrincham water supply is obtained from the Wood-Head source.

W.c.'s are in use over the greater part of the town; there are, however, a few privies, the contents of which are not dealt with at the sewage farm.

The streets sewered are principally macadam.

There is, practically, no manufacturer's effluent.

The sewerage system is on the combined method, all street, roof, and back-yard water being admitted to the sewers, and, consequently, during rainfall large fluctuations occur in the sewage flow. Very frequently the present outfall sewer is too small for the flow.

The average annual rainfall at Altrincham is 37in.

The whole of the sewage gravitates to the farm. Most of the sewers appear to be in fairly good condition; some, however, are 30 years old, and they allow a considerable amount of subsoil leakage. In addition, two small ditches run into the main sewer, where it passes by syphon under the Bridgwater Canal.

With the exception of the main gravitation outfall sewer the general lines of sewers have fairly good falls throughout. They are not flushed at any point.

The whole of the sewage is carried as far as West Timperley Station by two ovoid brick sewers, which discharge into a chamber provided with a storm overflow cill and iron flap valve, opened during storms by the head of sewage and storm water, which is discharged through a 3ft. 9in. circular brick culvert into an adjoining stream, this stream eventually joining the brook which receives the farm effluent. At present this main storm overflow works at less than one of storm water to one of sewage, or less than twice the dry weather flow. There are, in addition, two other local storm overflows.

From this chamber the 21in. main outfall to the sewage farm commences, laid at a gradient of 1 in 2,174, and having a theoretical capacity, running full, of about 1,800,000 gallons per 24 hours. About 150 yards from this chamber the 21-in. outfall sewer passes through a small catch-pit 20ft. by 2ft. by 2ft. deep, and any accumulation of silt or sand (such as that caused by laying a new sewer) is extracted here when necessary. After leaving this catch-pit the sewage is conveyed to a small settling tank on the farm; the distance from the storm overflow chamber to the settling tank being about

2,130 yards. The outfall sewer being at such a flat gradient has not a self-cleansing velocity, and has a tendency to silt up rapidly in consequence.

The average time taken by the sewage to reach the farm is about $3\frac{1}{2}$ hours.

The settling tank is 70ft. long by 6ft. wide and 3ft. 9in. deep (average depth), formed with a circular bottom. The working capacity is about 10,000 gallons, or $\frac{1}{80}$ of the dry weather flow. At the outflow end of the tank the channel for the sewage is 2ft. 4in. wide and 18in. deep, a sliding iron sluice door being employed to retain the solids in the tank as far as possible. The sludge is drawn off about once a week by means of a chain pump into an adjoining sludge bay, 68ft. long by 18ft. by 2ft. 6in. deep. When the sludge has dried sufficiently, it is mixed with farmyard manure and ploughed or dug into the land where required. The capacity of this tank is only very small in proportion to the daily flow of sewage, and consequently little appreciable settlement is effected. The maximum and strongest sewage flow at the farm occurs from about noon until 2 p.m., and the sewage is fairly fresh on its arrival at the farm. On leaving the settling tank the sewage passes over the farm, along a main carrier formed with a stone slab invert and brick sides (Add. B, III.); closed pipe carriers are also used.

The bricks used in the sides of the main carrier are not blue brick, and have perished badly with the frost, causing any grease, etc., in the sewage to accumulate against the sides, and hindering the cleansing of the carriers. From the main carriers the sewage either flows directly on to the land, or first into spade-formed subsidiary carriers, as the case may be.

The total area of the farm is at present (1900) 75·5 acres, 35 acres of which are irrigated (Add. B, I.). Taking the irrigable area (viz., 35 acres) as dealing with 800,000 gallons of sewage per 24 hours (exclusive of storm water), and a population of 18,000, this comes to 514·4 persons per acre, or about 23,000 gallons per acre; and since in dry weather about one-half of the irrigable area is sewaged at one time, this gives about 46,000 gallons of sewage treated per acre per 24 hours.

The irrigated area is under-drained 4 to 5 yards apart with ordinary 4-in. land tiles, about 3ft. 6in. to 4ft. deep, laid parallel and joining 9-in. stoneware socketted master drains, which are connected up to brick effluent manholes. The peat excavated in draining operations was not replaced over the drains, only good soil being returned, as it was found that the peat did not purify the sewage. Thus, it may be seen that the sewage has an average depth of about 3ft. of soil to pass through before reaching the under-drains.

There appears to be a little subsoil water present in the drains in wet weather.

The land is not liable to floods.

* Owing to the insufficient capacity of existing settling tank, the settled sewage is usually run into a plot of land banked round so as to form a lagoon of two or three acres, and sufficiently large to contain about one day's sewage flow (Add. B, III.). The suspended matter left in the settled sewage after passing through the tank is almost entirely deposited here, and the surface water drawn off at the foot of the plot, either direct, or by earthen carriers to the plots of land to be irrigated.

A portion of this impounded sewage also filters through the soil to the under-drains when the lagoon is first filled, the surface of the soil subsequently silting up and becoming more and more impervious to filtration. After the lagoon has been in use for three or four months, it is dried, the sludge ploughed in, and a fresh lagoon made; the sludge attaining an average depth of about 3in. in that time. To lessen the silting up of the lagoons, small sludge arresters were placed at the openings where the settled sewage entered the lagoons (see plan); these, however, were not found to effect any appreciable difference.

The sewage and lagoon liquor is generally run on to the same plots intermittently for periods varying from fourteen to twenty-eight days, being turned on to the plots continuously for about twelve hours.

In winter the sewage is sometimes applied to the land continuously

* This (*i.e.*, lagoons) method was found not to be practicable in hot weather, the scum rising from the bottom of the lagoon in floating masses and creating a nuisance.

both night and day. At such times there is considerable risk of the frost raising the banks or "fenders" of the lagoons, and allowing the sewage to escape unpurified.

Crude sewage is occasionally applied to the land from the main outfall before it reaches the settling tank, holes having been made in the sewer to admit of this being done.

Twelve of the thirty-five irrigable acres are laid out in osier beds, and under the present conditions some of the drains come under the intervening grips, instead of down the centre of each bed, and the sewage in consequence gets through the soil too quickly.

The osier roots penetrate to a great depth, and are apt to choke up or displace the drain tiles when not laid deep, in addition to consolidating the ground and rendering it difficult for the sewage to pass through. The osiers nearest to the carriers, and where the sludge tends to accumulate, are much the largest, but very brittle, full of pith, and inferior in quality as compared with the rest. They appear to encourage a dense growth of weeds, and require almost incessant cleaning.

The beds are sewaged alternately, one set of beds resting while the others are receiving sewage, otherwise they do not dry. As a general rule, they are sewaged by night only.

The remainder of the irrigable land is arable, with the exception of a small piece of meadow land near the brook, which, however, is only used for sewage treatment during very heavy storms, and when the sewage cannot be kept back. The principal crops grown are mangolds and cabbages, the mangolds being sown on ridges, and the sewage run between them.

Rye grass is not grown much as a rule, there being a difficulty about its disposal.

All the crops grown on the farm are sold. The farm receipts generally just balance the payments, exclusive of interest on loan; so that the actual cost of treating the sewage amounts to the rental of the farm, or the interest on the loan for its purchase, equal to about £340 per annum, or £1·16 per 1,000,000 gallons, excluding storm water.

The total capital outlay on the farm up to the present date, including purchase and laying out of the land, has been about £14,000.

Three separate outfalls convey the effluent to the Sinderland Brook, which borders the farm.

This brook is frequently polluted by tan refuse. A large storm overflow culvert from another district also discharges into the stream, a little distance above the Altrincham Sewage Farm.

The ratio of effluent to brook water, normally, is approximately as one to three. The stream does not appear to be in a very satisfactory state, and contained (at the time of the visits to the farm) sewage weed for about 500 yards below the lowest effluent outfall. The only objectionable smell on the farm was that caused by the floating masses of scum on the lagoon surface previously alluded to.

The chief difficulty in working the farm is the want of sufficient land, and it is proposed to purchase 76·5 acres of the adjoining land, to construct new settling tanks, and to enlarge the present outfall sewer.

Notes on Temperature, Rainfall, etc.

The mean daily temperature on the Altrincham Sewage Farm was 10·2° C. (50·5° F.) for the first visit (April 24th to May 15th, 1900) with mean daily maximum and minimum temperatures of 16·4° C. (61·6° F.) respectively. On three nights there were frosts, the lowest reading being −4·4° C. (24° F.) on April 25th. Rain fell on 13 days out of 22. The greatest amounts during the 24 hours were ·45 in., ·32 in., and ·24 in. The mean daily rainfall was ·073 in. The mean daily temperature for about the same period of the following year (April 16th to May 11th, 1901) was 11·7° C. (53·2° F.), or 1·5° C. (2.7° F.) more than in 1901. The mean daily maximum and minimum readings were 18·9° C. (65·9° F.) and 4·7° C. (40·6° F.). The humidity averaged 79·8 daily. The mean daily rainfall was ·026 in. The greatest amounts recorded were ·20 in. on April 16th, and ·12 on the 2nd and 9th of May. Rain fell on 10 days out of 26 (see Add. B, V. and VI.).

ALTRINCHAM SEWAGE FARM.—TABLE I.

Domestic Sewage.

Number of Sample.	Date of drawing sample.	Time of day.	Rainfall day previous to drawing sample.	Rainfall day of drawing sample.	Atmospheric temperature time of drawing sample.	Temperature of sample.	Maximum temperature during the 24 hours.	Minimum temperature during the 24 hours.	Humidity (9 a.m.)	Dissolved oxygen in sample.	Brief description of Sample.	Remarks.
	1900		Inches	Inches		°C. °F.	°C. °F.	°C. °F.				
64	April 26	10.15 a.m.	·00	01		9·4 (49)	15· (59)	5·5 (42)			Settled sewage	* Mean daily maximum temperature 16·4 °C (61·6) °F.
65	,, ,,	11.30 ,,	,,	,,		8·3 (47)	,, ,,	,, ,,			Lagoon effluent	,, ,, minimum temperature 4·1 °C (39·5) °F.
66	,, ,,	12.15 p.m.	,,	,,		,, ,,	,, ,,	,, ,,			Final effluent	,, ,, rainfall ·073 in.
67	,, 29	1.0 ,,	·09	·10		10· (50)	15·5 (60)	6·6 (44)			Storm water	
68	,, ,,	2.0 ,,	,,	,,		10·5 (51)	,, ,,	,, ,,			,, ,,	
69	,, 30	11.50 ,,	·10	·00		13·3 (56)	,, ,,	0· (32)			Lagoon effluent	* For the period April 24th to May 15th, 1900.
70	,, ,,	1.15 ,,	,,	,,		8·8 (48)	,, ,,	,, ,,			Final effluent	
71	May 7	11.45 a.m.	·32	,,		11·1 (52)	20·5 (69)	3·3 (38)			Brook water	
72	,, ,,	11.50 ,,	,,	,,		,, ,,	,, ,,	,, ,,			† General effluent	NOTE.—Samples which may have been affected by rainfall are underlined.
73	,, ,,	12.5 p.m.	,,	,,		,, ,,	,, ,,	,, ,,			Brook water and effluent	
74	,, ,,	12.15 ,,	,,	,,		,, ,,	,, ,,	,, ,,			,, ,, ,,	
75	,, 15	11.30 a.m.	·00	·005		10·0 (50)	,, ,,	1·6 (35)			Settled sewage	† By "General" effluent is meant a mixture of two or more finally treated effluents on leaving the farm.
76	,, ,,	1.0 p.m.	,,	,,		8·8 (48)	,, ,,	,, ,,			Final effluent	
77	,, 16	11.50 a.m.	·005	00		9·4 (49)						
78	,, ,,	12.20 p.m.	,,	,,		,, ,,					Subsoil water	
	1901.				C. F.	C. F.	C. F.	C. F.		c.cs.		
248	April 16	11 10 a.m.	·12	·20	6·1 (43)	5·5 (42)	1·1 (44)		98		Final lagoon effluent	* Mean daily maximum temperature 18·9 °C (65·9) °F.
249	,, 17	10.45 ,,	·20	·04	8·3 (47)	7·2 (45)	10· (50)	·5 (33)	86		Settled sewage	,, ,, minimum temperature 4·7 °C (40·6) °F.
250	,, ,,	12 (noon)	,,	,,	9·4 (49)	6·6 (44)	,, ,,	,, ,,	,,	1·	Final effluent	,, ,, rainfall ·026 in.
251	,, ,,	12.30 p.m.	,,	,,	10· (50)	,, ,,	,, ,,	,, ,,	,,		,, ,,	,, ,, humidity 79·8
251A	,, 18	2.0 ,,	·04	·00	12·2 (54)	8·3 (47)	13·8 (57)	5·5 (42)	93		Brook water	
251B	,, 19	11.15 a.m.	·00	,,	13·3 (56)	7·7 (46)	23·8 (75)	3·3 (38)	71		Final effluent	
252	,, 22	11.10 ,,	,,	,,	23·3 (74)	8·8 (48)	22·7 (73)	9·4 (49)	87		,, ,,	
253	,, ,,	11.20 ,,	,,	,,	,, ,,	,, ,,	,, ,,	,, ,,	,,		,, ,,	* For the period April 16th to May 11th, 1901.
254	,, ,,	11.45 a.m	,,	,,	23·8 (75)	7·7 (45)	,, ,,	,, ,,	,,		,, ,,	
255	,, ,,	12 (noon)	,,	,,	,, ,,	10· (50)	,, ,,	,, ,,	,,		Lagoon effluent	
264	,, 30	,, ,,	,,	,,	19·4 (67)	17·7 (64)	23·3 (74)	4·4 (40)	80		Settled sewage	
265	,, ,,	12.30 p.m.	,,	,,	,, ,,	17·2 (63)	,, ,,	,, ,,	,,		First lagoon liquor	
266	,, ,,	1.0 p.m.	,,	,,	20· (68)	16·6 (62)	,, ,,	,, ,,	,,		Second lagoon liquor	
267	May 1	10.45 a.m.	,,	,,	15·5 (60)	10· (50)	13·8 (57)	5·5 (42)	,,	·75	Final lagoon liquor	
267A	,, ,,	11.0 a.m.	,,	,,	16·1 (61)	10·5 (51)	,, ,,	,, ,,	,,	3·50	Brook water and effluent	
274	,, 7	2.30 p.m.	·07	·02	11·6 (53)	11·1 (52)	12·7 (55)	·5 (33)	,,	1·	Final lagoon liquor	
274A	,, ,,	3.0 p.m.	,,	,,	11·1 (52)	,, ,,	,, ,,	,, ,,	,,	2·	Brook water and tan refuse	
275	,, 8	11.30 a.m.	·02	·03	13·8 (57)	10· (50)	19·4 (67)	7·2 (45)	93		Final lagoon liquor	
276A	,, ,,	12 (noon)	,,	,,	13·3 (56)	,, ,,	,, ,,	,, ,,	,,	2·	Brook water and effluent	
276	,, ,,	12.30 p.m.	,,	,,	12·7 (55)	,, ,,	,, ,,	,, ,,	,,	·50	Final effluent	

ALTRINCHAM SEWAGE FARM.

(Domestic Sewage.—Additional Notes on Samples.)

Sample No. 65.—The lagoon from which this sample was drawn had been in use (at the time of drawing the sample) since April 1st, 1900.

Sample No. 66.—This effluent appeared to contain a large amount of iron, and the beds of streams in the neighbourhood are covered with a deep reddish ochreous deposit.

Sample No. 67.—This sample was drawn after the storm overflow had been running for 30 minutes. The brook into which the discharge took place was in a filthy condition, owing to the paper and fæces flowing into it; ·10in. rainfall in about 3½ hours on a saturated surface caused the overflow.

Sample No. 68.—This sample was drawn after the overflow had been working for 1½ hours.

Samples Nos. 69 and 70.—The sewage from which these samples were produced was very dilute owing to the rainfall the previous day. Sample No. 70 was from a plot which had been sewaged with lagoon liquor intermittently for seven days. The sewage was run on for about 12 hours, then a rest of 12 hours, before any further sewaging. Rain appears to wash out yellow colouring matter from the under-drains.

Sample No. 71.—Brook water taken 13 yards above first effluent outfall. The brook was in flood, and the water turbid; a slight greasy film on the surface of the water. (Add. B. II.)

Sample No. 72.—General effluent taken from both effluent outfalls. Volume of stream to effluent approximately as six to one; effluent discoloured, reddish matter in suspension.

Sample No 73.—Brook water and effluent taken 175 yards below last effluent outfall, as the brook and effluent did not appear to mix thoroughly until that point was reached. There were large masses of sewage fungus discoloured with iron growing in the bed and sides of the stream.

Sample No. 76.—This effluent was from night sewage. The sewage takes a long time to pass through the osier beds, as the roots consolidate the ground.

Sample No. 77.—This sample was from the same sewage as No. 76, and also from the same plot previously sewaged; *i.e.*, the sewage in the grips between the osier beds had not yet all passed through to the under-drains.

Sample No. 78.—Subsoil water drawn from a trench sunk 3ft. 6in. deep. The water percolated into the hole through a stratum of very fine white sand, and was very milky in appearance.

Sample No. 248.—Final lagoon effluent, after passing through three lagoons and filtering through to the under-drains. Effluent had a sewage and iron smell. The lagoons (three in series) had previously been treating sewage intermittently for one month. The plot had been sewaged continuously for 18 hours before the sample was taken.

Sample No. 251A.—Brook water taken above effluent outfalls. Brook in flood owing to recent heavy rains.

Sample No. 251.—Final effluent from osier beds. These beds had been treated with crude sewage prior to passing through the settling tank. The beds had been sewaged intermittently throughout February (1901).

Sample No. 252.—The land from which this effluent was taken had not been sewaged since February (1901).

Sample No. 253.—This effluent was from settled sewage.

Sample No. 254.—This effluent was from crude sewage.

Sample No. 255.—Filtration effluent from lagoons.

Sample No. 265.—This effluent was taken from the surface of the first lagoon just before entering the second lagoon.

Sample No. 266.—This effluent was drawn in a similar manner to No. 265, but from the second lagoon.

Sample No. 267.—This effluent was a filtration one from the three lagoons.

Sample No. 267A.—Brook and effluent taken 150 yards below the last effluent outfall.

Sample No. 274A.—Brook water above effluent outfalls; some tan liquor was passing down the brook at the time.

Sample No. 274.—Filtration effluent from lagoons. This sample and No. 267 were taken after some old land drains had been stopped. There appeared previously to be a chance of the sewage having gained admission to the effluent through these drains.

Sample No. 275.—Surface effluent taken from the third lagoon, in a similar manner to Nos. 265 and 266.

Sample No. 276A.—Brook water a dirty colour, and a good deal of sewage weed in the bed and sides of the stream.

ALTRINCHAM SEWAGE FARM.—TABLE II.

Domestic Sewage.

No. of Sample.	Number of times the sewage is passed through or over the soil.	Area of plot or plots sewaged at the time of drawing sample.	Length of time these plots had been sewaged previously to drawing sample.	Nature of crops grown on plots.	Remarks.
		Acres.			
65	*Once	2·80	*26 days	Arable—no crops	Lagoon liquor* (surface) cloudy greenish colour. Slight sewage smell. Sewage running on continuously by day and night.
66	Twice	1·0	7 days (intermittently)	Ridged arable (sown mangolds)	Final effluent (filtration). Iron film on surface, some red flocculent matter.
67					Liquor from storm overflow.
68					,, ,, ,,
69	Once	2·80	30 days	Arable—no crops	Lagoon liquor (surface), cloudy.
70	Twice	1·0	2¼ hours	Ridged arable (sown mangolds)	Final effluent (filtration). Sample taken after 4,000 gallons had passed on to the ridged land.
71					Brook water taken above effluent outfalls.
72					General effluent, turbid and reddish yellow colour.
73					Brook water and effluents taken 175 yards below last effluent outfall.
74					Brook water and effluents taken 250 yards below last effluent outfall.
76	Once	2·25	9½ hours	Osiers	Final effluent (filtration). This effluent was from night sewage.
77	Once	2·25	9½ hours	,,	Final effluent (filtration). This effluent was from night sewage.
78					Subsoil water drawn 3ft. 6in. deep, milky appearance, apparently full of lime.
248	3 times	2·50	18 hours	Arable—no crops	Final effluent (filtration) after passing through 3 lagoons (in series).
250	,,	2·50	14 hours	,, ,,	Final effluent (filtration) after passing through 3 lagoons (in series).
251A					Brook water above effluent outfalls, brook in flood.
251	Once	5·0	5 hours	Osiers	Final effluent.
251B	3 times	2·50	10 hours	Arable—no crops	Final filtration lagoon effluent (as Nos. 248 and 250), red iron colour.
252	Once	·50	4 hours	Ridged arable	Final effluent, iron smell.
253	,,	5·0	11 hours	Osiers	Final effluent, fairly clear.
254	,,	4·0	4 hours	,,	Final effluent, some red flocculent suspended matter.
255	3 times	2·50	1 day	Arable—no crops	Final effluent (filtration) after passing through 3 lagoons (in series).
265	Once	·83	,,	,, ,,	Liquor (surface) from 1st lagoon.
266	Twice	·83	,,	,, ,,	,, ,, ,, 2nd ,,
267	3 times	·83	,,	,, ,,	,, (filtration) ,, 3rd ,,
267A					Brook water taken 150 yards below last effluent outfall. Brook normal.
274	,,	2·50	,,	,, ,,	Final filtration effluent from lagoons, deep yellow colour, iron film.
274A					Brook water above effluent outfalls, tan refuse coming down.
275	,,	2·50	2 days	,, ,,	Surface liquor from last lagoon, cloudy turbid colour, sewage small.
276	,,	2·50	,,	,, ,,	Filtration liquor from last lagoon, yellow colour.
276A					Brook water taken below effluent outfalls. Water a dirty colour.

ALTRINCHAM SEWAGE FARM.—TABLE III.

Domestic Sewage.

SEWAGE SAMPLES.

Number of Sample.	Time of drawing Sample.	Nature of Sewage.	Remarks.
64	10.15 a.m.	Settled sewage.	From catchpit or tank. Very dilute.
75	11.30 a.m.	,, ,,	,, ,, ,, ,, Fairly strong.
249	10.45 a.m.	,, ,,	,, ,, ,, ,, Very dilute.
264	12 (noon)	,, ,,	,, ,, ,, ,, Fairly strong.

* COMPARATIVE SAMPLES—TABLE IV.

(or Samples taken from the same plots of land).

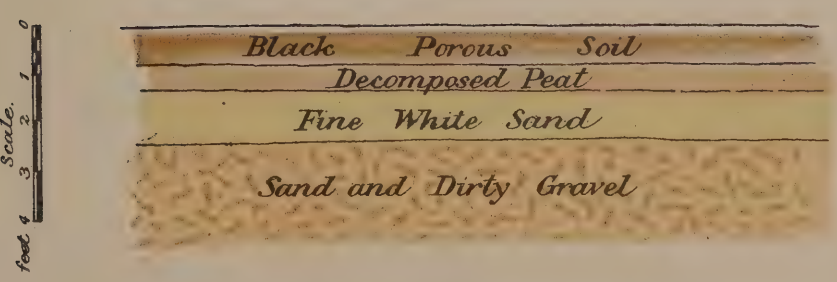
Lagoon effluents.	Other effluents.	Remarks.
(65)	(76)	* By "Comparative Samples" is meant samples drawn from the same areas of land, and the effluents in brackets are comparable with each other so far as the area of land sewaged is concerned.
† (69)	(77)	† These samples were from the surface liquor of the lagoon.
* (248)		* These samples were from the effluent which filtered to the drains underlying the three lagoons.
* (250)		
* (251b)		
* (255)		
* (267)		
* (274)		
276)		

ALTRINCHAM SEWAGE FARM.

ALTRINGHAM SEWAGE FARM.

Scale :- 25·344 Inches to One Mile.

ALTRINGHAM SEWAGE FARM.

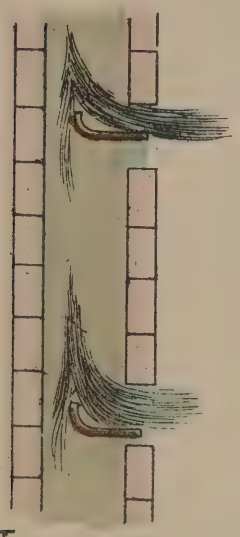


SECTION OF SOIL.

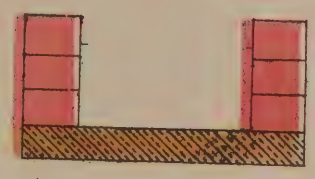
8311. 7. 1902.

Weller & Graham. Ltd Litho. London.

ALTRINCHAM SEWAGE FARM.

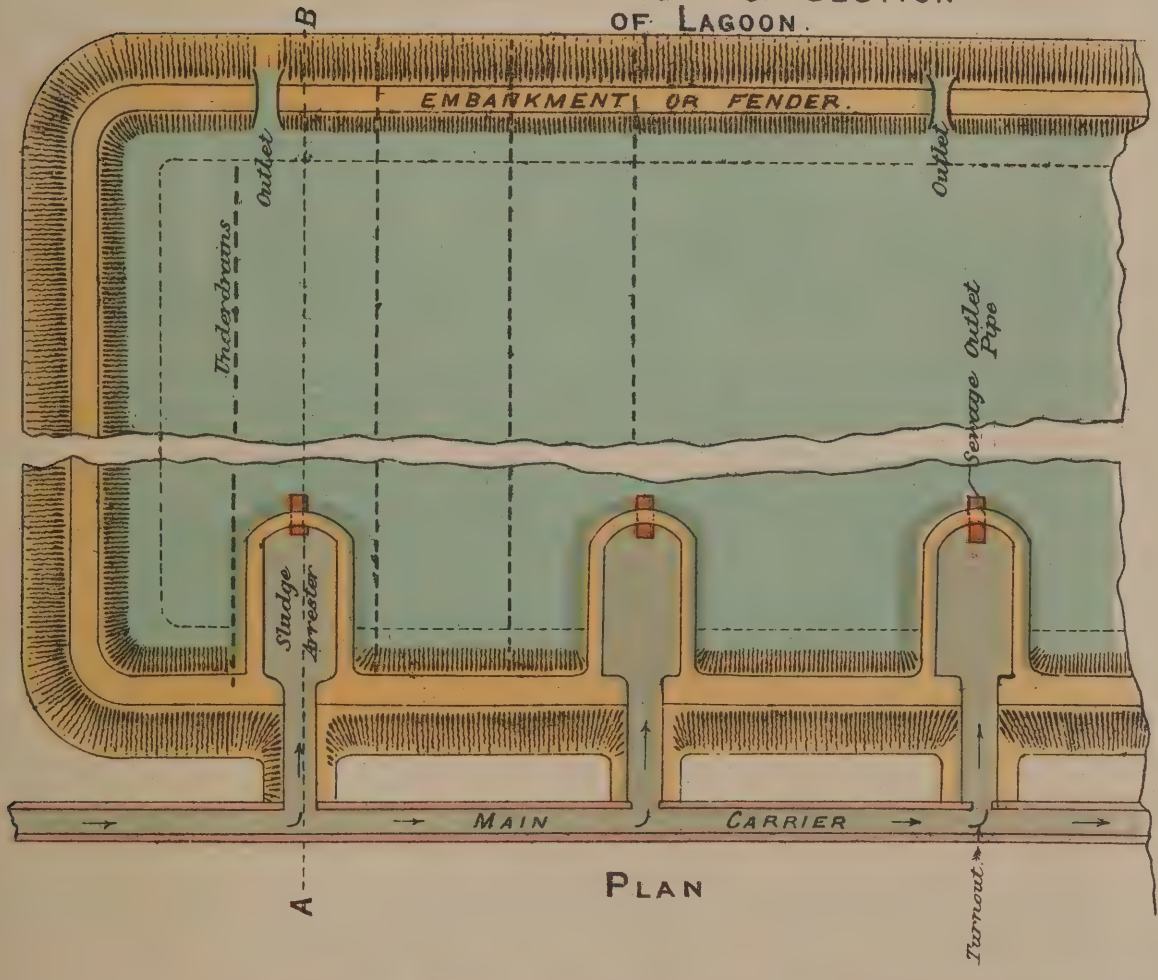


PLAN OF TURNOUTS FOR SEWAGE.



SECTION OF MAIN CARRIER

DIAGRAMMATIC PLAN & SECTION OF LAGOON.



PLAN

SECTION A.B.

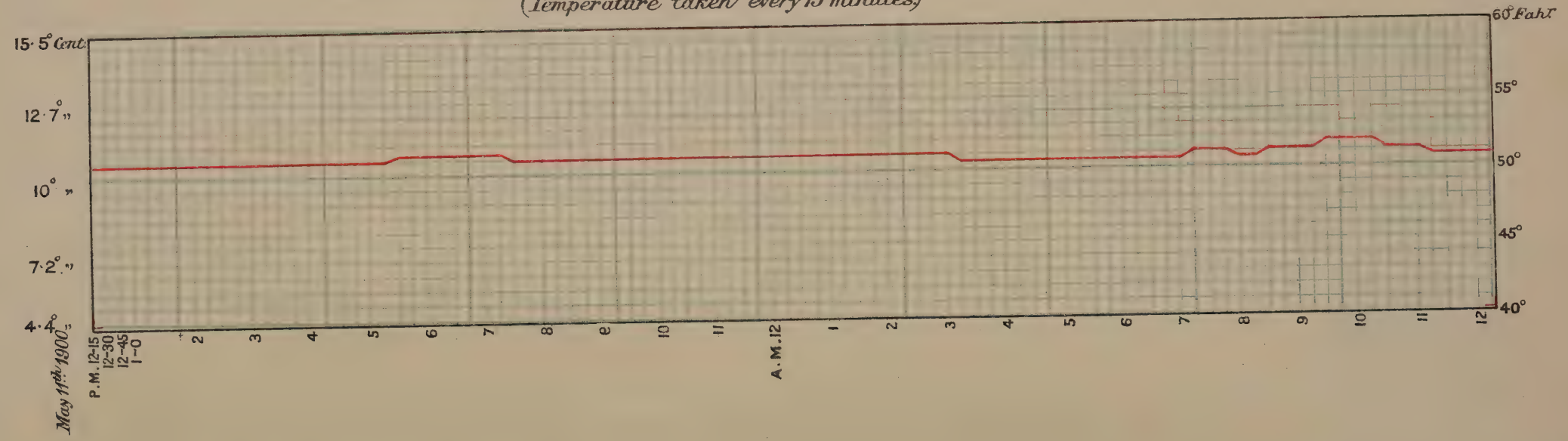
Weller & Graham, Ltd Litho. London.

Addendum B.

IV.

ALTRINCHAM SEWAGE FARM.

Hourly variations in Temperature of Crude Sewage during the 24 hours.
(Temperature taken every 15 minutes.)

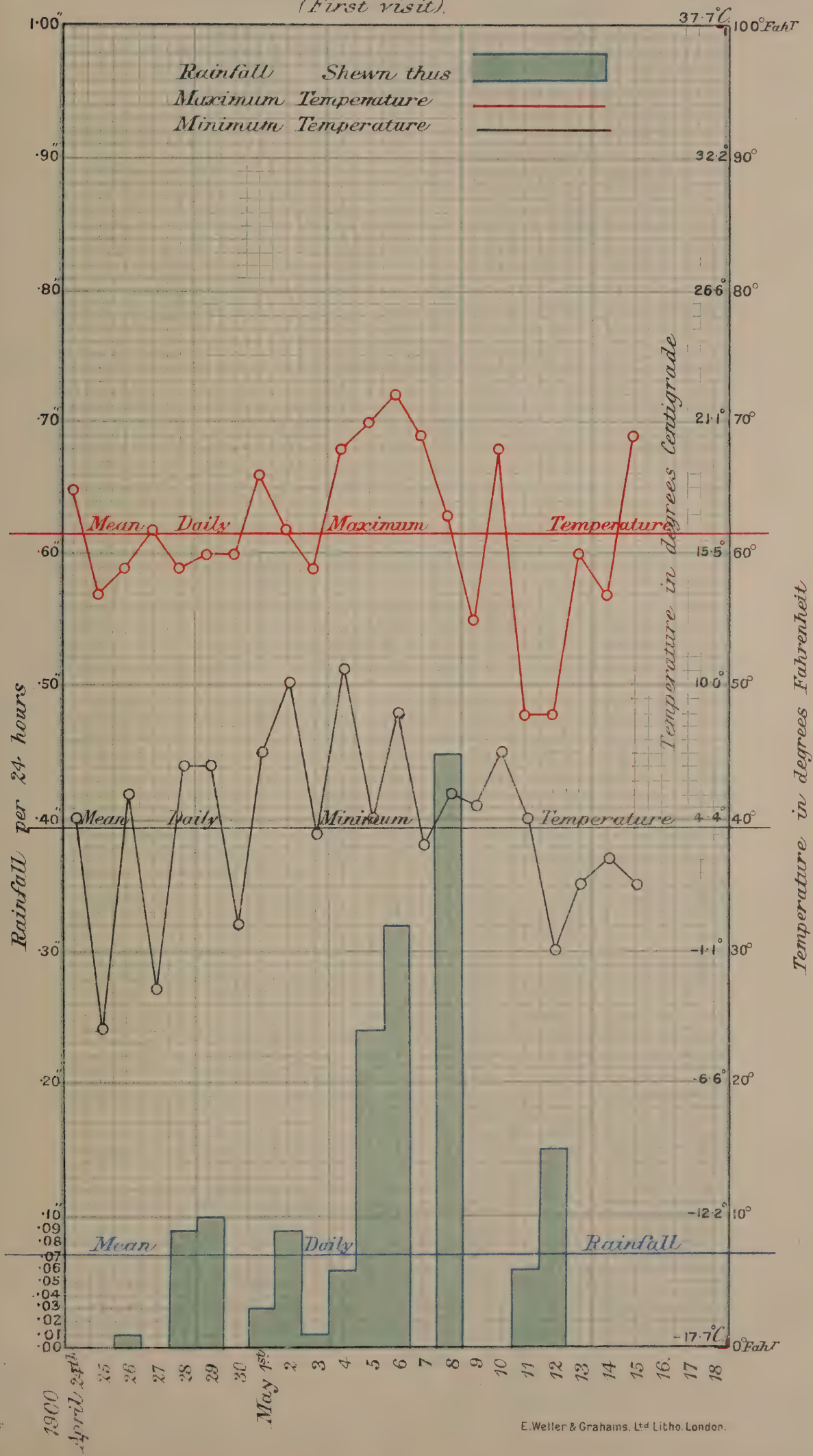


Weller & Grahams. Ltd Litho. London

3311. 9. 02

ALTRINCHAM SEWAGE FARM.

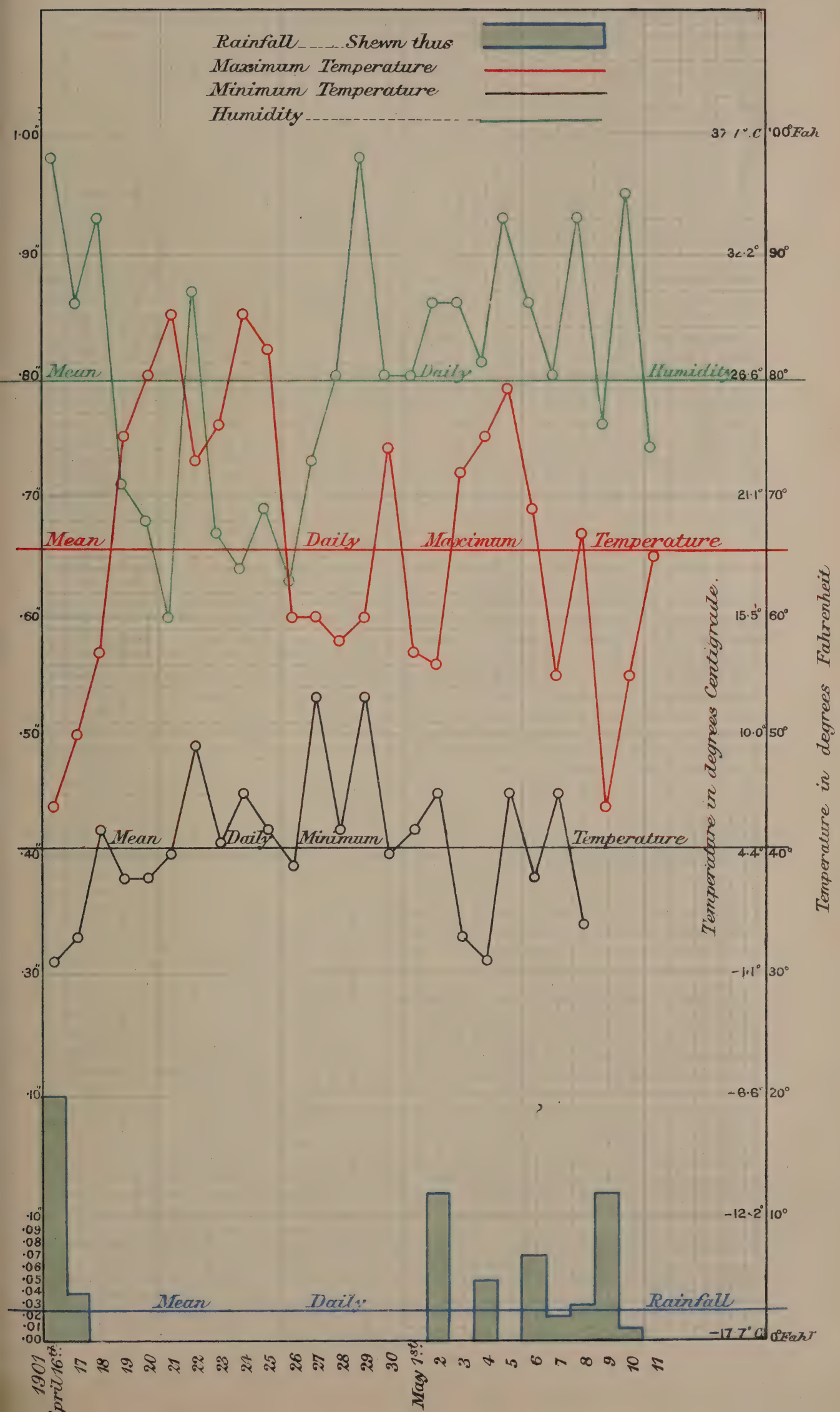
(First visit).



E. Weller & Grahams. Ltd Litho. London.

ALTRINCHAM SEWAGE FARM.

(2nd Visit.)



CROYDON (Beddington) SEWAGE FARM.

(Croydon Corporation.)

1. Situation of farm—Beddington, about 3 miles from Croydon.
2. Total acreage of farm—673·5 acres.
3. Total irrigable area.—420 acres.
4. Average area irrigated at one time—About 70 acres.
5. Population draining to farm—100,000.
6. ,, per acre irrigated—238.
7. Gallons of sewage per head per day—40.
8. Dry weather flow of sewage per 24 hours—4,000,000 gallons.
9. Gallons of sewage (exclusive of storm-water) treated per acre per 24 hours—57,100, $(\frac{4,000,000}{70})$
10. Gallons of sewage treated per acre per 24 hours, on the assumption that each acre of irrigable area is under sewage all the time. (This for purposes of comparison)—$(\frac{4,000,000}{420})$ = 9,500 gallons.
11. Characters of the sewage—Almost purely domestic.
12. Method of treatment.
    (*a*) Croydon—screening, surface irrigation and a little filtration.
    (*b*) Norbury—as above, but slight settlement in tanks in addition.
13. General characters of the soil and subsoil—Gravelly loam, over gravel and sand.
14. Separate or combined sewerage system—Partially separate.
15. The final effluent is discharged into—River Wandle.
16. Number of years farm in operation before 1900—39 years.

CROYDON (Beddington) SEWAGE FARM REPORT

SUMMARY OF CONTENTS.

DESCRIPTION OF FARM

Addendum A.—Notes on Samples.

Additional Notes on Samples.

Table I.—Shewing all samples drawn at the Croydon (Beddington) Sewage Farm, together with time of drawing, rainfall, temperatures, description of samples, etc.

Table II.—Giving area of plots from which samples were drawn, and the time those plots had been sewaged, etc.

Table III.—Comparative samples.

Table IV.—Sewage samples.

Addendum B.—Plans and diagrams referred to in report.

I.—Plan of farm.

II.—Plan referring to river samples, and section of soil and subsoil.

III.—Diagram showing hourly height of sewage in main carrier.

IV.—Temperature and rainfall chart—(1st visit).

V.— ,, ,, ,, ,, (2nd visit).

VI.— ,, ,, ,, ,, (Experiment).

VII.—Diagrams shewing number of gallons treated per acre during the experiment.

CROYDON SEWAGE FARM (BEDDINGTON).

(Croydon Corporation.)

Domestic Sewage.

The sewage contains a small amount (about 2 per cent., or 80,000 gallons per 24 hours) of laundry, brewery, and butchers' refuse, and is treated by screening followed by surface irrigation, and in parts filtration. The Norbury and Thornton Heath portion of the sewage in addition passes through small settling tanks.

The farm overlies the geological formation known as the Woolwich and Reading beds. The surface soil consists in most parts of from 12 to 18 inches of soil, varying from loam interspersed with gravel, to a somewhat lighter soil. (Add. B. II.) The subsoil varies, but it is chiefly gravel and sand of a depth of from 6 to 12 feet. Iron pan, more or less impervious, occurs in parts.

The farm has been used for sewage disposal for 39 years (1900). It is managed by the Croydon Corporation.

The districts draining to the farm are Croydon, Thornton Heath, and Norbury.

The average dry weather flow in gallons per 24 hours is :—

Thornton Heath and Norbury - - -	1,000,000
Croydon - - - - - - . -	3,000,000
Total - - -	4,000,000

or 40 gallons of sewage per head of the population sewered.

The population treated on the farm is :—

Croydon - - - - - -	75,000
Thornton Heath and Norbury - -	25,000
Total -	100,000 (about)

The drainage area of the districts sewered is 6,300 acres.

The public water supply is about 28 gallons per head ; the greater part is obtained from Corporation wells in the chalk, the remainder from the Lambeth Water Company.

The streets sewered are chiefly macadam.

About 31,000 w.c.'s are connected to the sewerage system. There are no privies.

The average annual rainfall at Croydon was: 1881 to 1890, 22·89 inches ; from 1891 to 1900, 24·70 inches ; and 1900 to 1901, 21·94 inches.

The present condition of the Croydon sewers is good, and it is stated that there is not a great amount of subsoil leakage, the quantity depending chiefly upon the height of the water level in the Croydon Valley.

The sewers are flushed with large automatic tanks, tipping tanks, flushing vans and hose. There are no storm overflows whatever, and the whole of the storm water reaching the sewers is treated on the farm together with and the same as the sewage.

The separate system is used on about half the drainage area for water from roads and front roofs ; back roofs, and back yards draining to the foul water sewers.

All the sewage gravitates to the farm from two outfall sewers, with a combined capacity when running full of 5,814 cubic feet a minute.

The Thornton Heath and Norbury sewer enters the farm on the N.E. and flows through two small settling tanks before passing on to the land. These tanks are in duplicate, each being 32 ft. long × 9ft. × 1 ft. average depth, provided with screens and scumboards, and are both used together on the continuous method. They are too small in proportion to the present sewage flow to effect much settlement. About 25 tons of wet sludge are produced at these tanks weekly, and it is carted on to the land and ploughed in. The sewage on leaving the tanks branches into two channels leading to the irrigation plots.

At Brimstone Barn the Croydon sewage passes through one of Lathams patent solid sewage extractors. They are in duplicate, worked by a turbine, the sewage itself providing the motive power. The extractor may be briefly described as resembling a circular wire sieve, revolving on a horizontal axis, the sewage flowing through the meshes leaves the solids in the sieve, and a revolving screw pushes the solid matter into a trough, from which it is removed to the farm and dug in.

The Croydon sewage, after passing through the extractor, flows on to the farm without any further treatment. The average time the sewage takes to reach the farm is about two hours. On its arrival at the farm the sewage flows along main carriers constructed of concrete, and from 2 ft. to 4 ft. 6 in. wide by about 2 ft. 6 in. deep, running along the top of the plots to be irrigated ; a wooden sluice is provided at any change of level, but as far as the ground allows, the carriers are laid level. (Add. B. III.). The sewage flows from lips in the carriers on to the land.

The flow of sewage in the various carriers is controlled and regulated by means of wooden sluices.

On passing from the carriers the sewage flows down plough-cuts made about 50 feet apart and running down the plots, following the greatest fall, and the intervening ground between these plough-cuts or trenches is "dished" or hollowed, to cause the sewage to meet between them and thus irrigate the whole of the land. The trenches and the dishing run out before the bottom of the plot is reached, and a pick-up carrier is run along the bottom of the plot, into which the effluent passes to be similarly re-treated over other plots. Iron and wooden stoppers are used in the trenches at intervals to divert the water on to the land. The sewage is treated from two to three times. The land has a very even slope towards the River Wandle, and is not liable to floods. There is not much subsoil water on the farm. The total area of farm is 673·5 acres, of which area 420 acres are actually irrigated. (Add. B. I.).

This area (excluding storm water) deals with 4,000,000 gallons of sewage per 24 hours throughout the year. With a population of 100,000 this gives 238 persons per acre of irrigable area, or about 9,520 gallons per acre, during a normal sewage flow. As about one-sixth of this irrigable area is under sewage at once, this is equal to 57,120 gallons of sewage treated per acre per 24 hours.

Only about 100 acres of the farm are underdrained, the underdrainage being put in for the purpose of assisting the land to dry after the sewage is taken off. Until about 14 years ago there was no underdrainage. The existing drains vary in depth from 4 to 9 feet, and 4 to 24 inches in diameter. The distances between the drains differ ; they are usually very wide apart. The drain trenches were filled in with the soil excavated. The drain effluent from the upper part of the farm can be repassed over the land lower down.

In dry weather the sewage is run on to the land continuously for 24 hours, which is then left to dry for from two to three days ; during storms, however, it is often necessary to run the sewage on to the same land for from three to five days. The sewage is treated on the 3—and sometimes 4—land treatment ; that is to say, it passes over three or four separate plots of land. Usually, but not invariably, the first field is arable land. In frosty weather it is usually run over the ploughed land and the the rye grass which is to be broken up. In the case of ice forming on the surface of the plots, the sewage continues flowing underneath it. Two main effluent outfalls convey the effluent to the River Wandle. The Wandle rises not far off Croydon, and is fed by springs in the chalk. The general condition of the river appears to be good, and there is evidently no nuisance derived from the mixture of effluent and river water. (The normal volume is stated to be about 24,000,000 gallons per 24 hours.) In wet weather this volume is greatly exceeded. The normal ratio of effluent to river water is about as 1 to 8.

There is, as a rule, no objectionable smell noticeable in the working of the farm. Occasionally in hot weather a certain amount of smell is traceable to some of the carriers, caused by offensive matter being arrested by the coarse herbage dipping into the carriers when not kept down sufficiently. The channel from the point where the sewage enters the farm is not

concreted for some distance and this renders effectual cleaning out a difficult matter, the bottom and sides being gravel and apt to become overgrown.

The chief crop grown on the farm is Italian rye grass. In 1900 about one-half of the irrigable area was rye grass, 100 acres permanent pasture (which is also irrigable), and about 100 acres of arable land. Mangolds, cabbages, and oats are also grown; the oats cannot be sewaged. Part of the crops are utilised on the farm premises and part are sold.

The cost of treating 1,000,000 gallons of sewage, exclusive of storm water, and interest on loan is—labour and screening, 4s. 10d.

The total capital outlay on the sewage farm up to the present date (1900) has been £210,366.

For the past five years the average annual loss on the farm has been :—

	£	s.	d.
Average annual loss on farm - - -	437	15	7
Sinking fund and interest - - - -	7,408	5	3
TOTAL -	£7,846	0	10

The chief difficulties in the working of the farm are the selling of the crops, and also the disposal of storm water in time of storms, all being treated on the land.

In heavy storms the sewage flow at the farm sometimes reaches 16,000,000 gallons per 24 hours, or four times the normal dry-weather flow. In wet weather, too, solids are apt to be washed on to the rye grass in masses, where it is extremely difficult to get rid of; in addition, large quantities of grease and scum are washed out of the sewers.

NOTES ON TEMPERATURE, RAINFALL, etc. :—

During the first visit to the Beddington farm (7th Feb. to 2nd March 1900) the rainfall was very heavy, averaging ·109 inch daily. Rain fell on sixteen out of twenty-four days. On six occasions the amount registered exceeded ·25 inch, the greatest falls being ·46 inch, ·35 inch (rain and snow) and ·32 inch. The weather was cold throughout the visit, the mean daily temperature being 4·2° C. (39·6° F.)

The mean daily maximum temperature during the second visit was high, being 16·1° C. (61°F.), whilst the lowest recorded temperature was —·5°C. (31° F.) Heavy rain (·42 inch) fell on 5th October. The mean daily temperature during the experiment (22nd October to 6th November 1900)—was 10·5° C. (50·9° F.) The mean daily rainfall was ·077 inch (See Add. B. IV., V., and VI.)

ADDITIONAL NOTES ON SAMPLES.

Samples, Nos. 37, 38, 39.—These samples were affected by the snow which fell two days previously, the fields irrigated being partially icebound, and covered with snow.

Sample No. 43.—This permanent pasture contained a great deal of water grass at the lower end.

Sample No. 45.—River Wandle water takes 340 yards above effluent outfalls. River slightly above normal height owing to rain,—water slightly discoloured.

Sample No. 46.—River water and effluent taken 130 yards below sample No. 44. Ratio of effluent to river water about as 1 to 12. No sewage weed apparently. (Add. B. II.).

Sample No. 47.—River water and effluent taken 230 yards below sample No. 46. No apparent signs of sewage weed. This sample could not be taken any lower down the river owing to the Carshalton effluent outfall.

Sample No. 150.—This first field had received too much sewage; the rye grass was in fair condition.

Sample No. 150a.—River water about effluent outfalls,—very clear; river about normal.

Sample No. 154a.—River water above effluent outfalls; river very fine and clear.

Sample No. 155.—The giving way of a brick culvert near the railway, and consequent lifting of a sluice gate, may possibly have affected this effluent injuriously.

Sample No. 155b.—River water and effluent taken 360 yards below effluent outfall; river clean and clear.

Sample No. 156a.—River water above effluent outfall; river very clear.

Sample No. 160a.—River water and effluent taken 360 yards below effluent ontfall; river rather high.

Experiment.

Two fields were chosen for this experiment, one arable field of 16 acres, and one rye grass field of 20 acres. The arable field was last sewaged on 8th October 1900. The rye grass field had been resting for a week. The field was ploughed 8 inches deep all over, a few days before the experiment began, and the soil seemed in a very clean condition. The last crop on this field was cabbages. The amounts of sewage put on were started at a constant flow (day and night) of 25,000 gallons per acre for the 16 acres per 24 hours, and this amount was increased daily by 5,000 gallons. The field was partially underdrained, and the filtration effluent was taken on to the rye grass field for second treatment. The sewage was turned on to the arable field on 23rd October 1900 at 11 a.m. The sewage was kept running on continuously at a constant rate both day and night. There was a very small amount of subsoil water under both the arable and rye grass fields, but not sufficient to influence the experiment prejudicially.

The sewage turned on the first day was rather dilute and very soapy.

Sample No. 161.—25,000 gallons per acre per 16 acres going on. Sewage only fairly strong and very soapy.

Sample No. 162.—Owing to there being only one carrier available for the entire field, only about 4 acres were being irrigated, the land absorbing a large quantity.

Sample No. 163*—6 acres irrigated. The sewage from which the effluent was derived contained a large amount of black sewer scourings.

Hardly any effluent going on to the second (rye grass) field as yet.

Sample No. 163a.—Arable field effluent now going on rye grass field. Sewage very black, and full of scourings.

Sample No. 163b.—This effluent, after leaving the arable field, had, in passing over the rye grass (1 acre), percolated through to the drains, the samples being drawn from a manhole.

Sample No. 163c.—Sewage normal.

Sample No. 163d.—Sewage about normal.

Sample No. 164b.—Sewage very dilute (from rain) and soapy. Samples 164b and 165 were taken when the sewage was going on to the arable field at the rate of about 83,000 gallons per 24 hours, or less than the usual dose of sewage the land receives ordinarily. The sewaging in the experiment had however been continuous, no rest being given to the fields.

Sample No. 166.—Sewage rather strong.

Sample No. 166a.—Taken about 360 yards below effluent outfall.

Sample No. 167a.—Sewage strong.

Sample No. 168.—Sewage soapy.

Sample No. 169.—This sample was a surface effluent from the rye grass, taken at foot of field.

After these last samples had been drawn, the sewage run on to the arable land was kept at a constant flow and then increased on 8th November to about 3,000,000 gallons per 16 acres per 24 hours, and kept at that flow until samples Nos. 172 and 173 were taken. The fields which had been sewaged during the experiment were again sewaged after a rest of 10 days, and had then recovered from the effects of the previous irrigation.

**Note.*—This is at the rate of 30,000 gallons per acre for 16 acres, or 480,000 gallons in all, but only 6 acres were actually receiving this quantity. For the sake of clearness a diagram is appended shewing the actual amounts of sewage treated per acre on both arable and rye grass fields. (Add. B. VII.)

TABLE I.

Domestic Sewage.

Number of Sample.	Date of drawing Sample.	Time of day.	Rainfall day previous to drawing Sample.	Rainfall day of drawing Sample.	Air Temperature time of drawing Sample.	Temperature of Sample.	Maximum Temperature during the 24 hours.	Minimum Temperature during the 24 hours.	Humidity (9 a.m.)	Dissolved Oxygen in Sample.	Brief description of Sample.	Remarks.
	1900:		Inches.	Inches.	°C. °F.	°C. °F.	°C. °F.	°C. °F.				
36	12 February	12.15 p.m.	·00	·00	—	9·4 (49)	5·5 (42)	-8·3 (17)	—	—	Screened sewage.	*Mean daily maximum temperature, 8·3 °C.(47 °F.) Mean daily minimum temperature, ·1 °C.(32·2 °F.) Mean daily rainfall, ·109 in.
37	12 „	2.45 „	·00	·00	—	1·1 (34)	5·5 (42)	-8·3 (17)	—	—	First field effluent.	
38	12 „	4.30 „	·00	·00	—	4·4 (40)	5·5 (42)	-8·3 (17)	—	—	Second „ „	
39	12 „	5.15 „	·00	·00	—	2·2 (36)	5·5 (42)	-8·3 (17)	—	—	Final „ „	*For the period 7th February to 2nd March 1900.
39a	15 „	12.30 „	·18	·46	—	1·1 (34)	7·7 (46)	1·6 (35)	—	—	§General „	
40	20 „	11.45 a.m.	·32	·00	—	10· (50)	13·8 (57)	-1·1 (30)	—	—	Screened sewage.	*Note.*—Samples which may have been affected by rainfall are underlined.
41	20 „	1.15 p.m.	·32	·00	—	8·3 (47)	13·8 (57)	-1·1 (30)	—	—	First field effluent.	
42	20 „	2.50 „	.32	·00	—	7·7 (46)	13·8 (57)	-1·1 (30)	—	—	Second „ „	§By "General" effluent is meant a mixture of two or more finally treated effluents on leaving the farm.
43	20 „	4 „	·32	·00	—	7·2 (45)	13·8 (57)	-1·1 (30)	—	—	Final „ „	
44	26 „	4.35 „	·05	·25	—	13·3 (56)	16·1 (61)	7·7 (46)	—	—	General effluent.	
45	26 „	4.15 „	·05	·25	—	12·2 (54)	16·1 (61)	7·7 (46)	—	—	River water.	
46	26 „	5.5 „	·05	·25	—	13·3 (56)	16·1 (61)	7·7 (46)	—	—	River water and effluent.	
47	26 „	5.30 „	·05	·25	—	11·1 (52)	16·1 (61)	7·7 (46)	—	—	„ „	
149	3 October	11.45 a.m.	·00	·00	12·7 (55)	15· (59)	15·5 (60)	5· (41)	—	c.cs. Less than 1. cc.	Screened and settled sewage.	*Mean daily maximum temperature, 16·1 °C.(61 °F.) Mean daily minimum temperature, 4·4 °C.(40 °F.) Mean daily rainfall, ·03 in.
150	3 „	2 p.m.	·00	·00	16·1 (61)	13·8 (57)	15·5 (60)	5· (41)	—	—	First field effluent.	
150a	3 „	2.30 „	·00	·00	12·2 (54)	11·6 (53)	15·5 (60)	5· (41)	—	—	River water.	
151	3 „	3.30 p.m.	·00	·00	13·8 (57)	12·7 (55)	15·5 (60)	5· (41)	—	—	Final effluent.	
152	8 „	11 a.m.	·00	·00	18·3 (65)	14·4 (58)	22·2 (72)	5·5 (42)	—	—	Screened and settled sewage.	
153	8 „	2.30 p.m.	·00	·00	20·5 (69)	15· (59)	22·2 (72)	5·5 (42)	—	5·	Final effluent.	
154	9 „	2 „	·00	·00	18·3 (65)	16·6 (62)	23·3 (74)	10·5 (51)	—	3·50	„ „	*For the period 3rd to 21st October 1900.
154a	9 „	2.30 „	·00	·00	17.7 (64)	14·4 (58)	23·3 (74)	10·5 (51)	—	8·	River water.	
155	10 „	1.45 „	·00	·00	14·4 (58)	14·4 (58)	22·2 (72)	11·6 (53)	—	1·50	Final effluent.	
155a	11 „	1.15 „	·00	·00	11·1 (52)	13·3 (56)	14·4 (58)	- ·5 (31)	—	7·	„ „	

TABLE I.—*continued.*

CROYDON SEWAGE FARM (Beddington)—Domestic Sewage—*continued.*

Number of Sample.	Date of drawing Sample.	Time of day.	Rainfall day previous to drawing Sample.	Rainfall day of drawing Sample.	Air Temperature time of drawing Sample.		Temperature of Sample.		Maximum Temperature during the 24 hours.		Minimum Temperature during the 24 hours.		Humidity (9 a.m.)	Dissolved Oxygen in Sample.	Brief description of Sample.	REMARKS.
	1900 :		Inches.	Inches.	°C.	°F.	°C.	°F.	°C.	°F.	°C.	°F.		c.cs.		
155b	11 February	1.35 p.m.	·00	·00	13·3	(56)	10·5	(51)	14·4	(58)	– ·5	(31)	—	7·	River water and effluent.	
156	15 „	2.45 „	·00	·025	10·	(50)	10·	(50)	12·2	(54)	0·	(32)	—	4·50	Final effluent.	
156a	15 „	3.15 „	·00	·025	10·	(50)	8·8	(48)	12·2	(54)	0·	(32)	—	10·	River water.	
157	16 „	12.45 „	·025	·00	10·5	(51)	10·	(50)	12·7	(55)	–2·7	(27)	—	6·25	Final effluent.	
158	17 „	12 (noon)	·00	·015	17·7	(64)	15·5	(60)	18·3	(65)	7·7	(46)	—	—	Screened sewage.	
159	17 „	5 p.m.	·00	·015	13·3	(56)	12·2	(54)	18·3	(65)	7·7	(46)	—	2·	Final effluent.	
160a	18 „	2.45 „	·015	·00	14·4	(58)	11·1	(52)	17·7	(64)	5·	(41)	—	—	River water and effluent.	
160	18 „	2.30 „	·015	·00	14·4	(58)	12·2	(54)	17·7	(64)	5·	(41)	—	2·	Final effluent.	
							EXPERIMENT :									
161	24 „	12·15 „	·015	·00	15·	(59)	14·4	(58)	15·	(59)	3·8	(39)	—	—	Screened sewage.	*Mean daily maximum temperature, 14·1 °C (57·4 °F.) Mean daily minimum temperature, 6·8 °C (44·4 °F.) Mean daily rainfall, ·077 in.
162	24 „	2.30 „	·015	·00	15·5	(60)	13·8	(57)	15·	(59)	3·8	(39)	—	1·	First effluent.	
163	25 „	12.30 „	·00	·045	13·3	(56)	13·3	(56)	15·5	(60)	11·6	(53)	—	·50	„ „	
163a	26 „	12.15 „	·045	·21	7·2	(45)	13·8	(57)	13·8	(57)	5·	(41)	—	—	„ „	
163b	26 „	12.45 „	·045	·21	7·2	(45)	11·6	(53)	13·8	(57)	5·	(41)	—	—	Final effluent.	
163c	27 „	12.45 „	·21	·00	10·5	(51)	12·2	(54)	12·2	(54)	0·	(32)	—	2·	„ „	
163d	29 „	12 (noon)	·145	·030	12·7	(55)	13·3	(56)	12·7	(55)	8·3	(47)	—	0·0	First „	*For the period 22nd October to 6th November, 1900.
164	29 „	12.45 p.m.	·145	·030	12·2	(54)	11·6	(53)	12·7	(55)	8·3	(47)	—	2·25	Final „	
164a	31 „	11.30 a.m.	·55	·015	18·3	(65)	14·4	(58)	17·7	(64)	8·8	(48)	—	—	Screened sewage.	
164b	31 „	12.45 p.m.	·55	·015	18·8	(66)	12·7	(55)	17·7	(64)	8·8	(48)	—	—	First effluent.	
165	31 „	1 „	·55	·015	18·8	(66)	11·6	(53)	17·7	(64)	8·8	(48)	—	2·	Final „	
166a	2 November	11.20 „	·115	·09	14·4	(58)	11·6	(53)	16·1	(61)	9·4	(49)	—	6·	River water and effluent.	
166	2 „	12.40 „	·115	·09	14·4	(58)	12·2	(54)	16·1	(61)	9·4	(49)	—	—	Final effluent.	
167a	3 „	12.20 „	·09	·00	14·4	(58)	13·3	(56)	13·8	(57)	10·	(50)	—	—	First „	
167	3 „	12·30 „	·09	·00	14·4	(58)	12·2	(54)	13·8	(57)	10·	(50)	—	1·75	Final „	
168	5 „	12.50 „	·00	·015	14·4	(58)	12·2	(54)	13·8	(57)	9·4	(49)	—	1·00	„ „	
169a	6 „	12 (noon)	·015	·015	13·8	(57)	12·7	(55)	15·	(59)	8·8	(48)	—	—	First „	
169	6 „	12.40 p.m.	·015	·015	13·3	(56)	12·7	(55)	15·	(59)	8·8	(48)	—	4·	Final „	
172	9 „	3.15 „	·24	·05	10·5	(51)	11·1	(52)	10·5	(51)	6·1	(43)	74	—		

	1901:															
369	7 October	12.30 p.m.	·18	·00	10·	(50)	10·	(50)	11·1	(52)	5·	(41)	—	—	General effluent	Slight yellow colour.
370	7 ,,	2. ,,	·18	·00	10·5	(51)	10·	(50)	11·1	(52)	5·	(41)	—	—	Final ,,	Clear.
371	7 ,,	1.30 ,,	·18	·00	10·5	(51)	10·5	(51)	11·1	(52)	5·	(41)	—	—	,, ,,	,,
372	7 ,,	2 p.m.	·18	·00	10·	(50)	13·8	(57)	11·1	(52)	5·	(41)	For the period 7th October to 11th October, 1901 - Mean daily maximum temperature, 13·4 °C (56·2) °F. Mean daily minimum temperature, 5·2 °C (43·2) °F. Mean daily rainfall, ·006 inches.		Screened sewage	Dilute after rainfall.
373	8 ,,	11.45 a.m.	·00	·03	13·3	(56)	14·4	(58)	11·6	(53)	5·	(41)			,, ,,	,, ,,
374	8 ,,	12. (noon)	·00	·03	13·3	(56)	11·1	(52)	11·6	(53)	5·	(41)			Final effluent	Clear, no smell.
375	8 ,,	12.15 p.m.	·00	·03	13·8	(57)	11·1	(52)	11·6	(53)	5·	(41)			,, ,,	,, ,,
376	8 ,,	12.30 ,,	·00	·03	13·3	(56)	11·6	(53)	11·6	(53)	5·	(41)			General effluent	Fairly clear.
377	9 ,,	10.30 a.m.	·03	·00	11·6	(53)	14·4	(58)	15·	(59)	8·8	(48)			Screened sewage	Rather weak.
378	9 ,,	11. ,,	·03	·00	11·1	(52)	13·3	(56)	15·	(59)	8·8	(48)			Final effluent	Clear.
379	9 ,,	11.30 ,,	·03	·00	11·1	(52)	13·3	(56)	15·	(59)	8·8	(48)			,, ,,	,,
380	9 ,,	12.10 p.m.	·03	·00	11·1	(52)	13·3	(56)	15·	(59)	8·8	(48)			General effluent	Rather cloudy.
381	10 ,,	10.45 a.m.	·00	·00	12·2	(54)	14 4	(58)	15·5	(60)	3·8	(39)			Screened sewage	Normal.
382	10 ,,	11. ,,	·00	·00	14·4	(58)	14·4	(58)	15·5	(60)	3·8	(39)			Final effluent	Clear.
383	10 ,,	11.30 ,,	·00	·00	12·2	(54)	13·3	(56)	15·5	(60)	3·8	(39)			,, ,,	,,
384	10 ,,	12. (noon)	·00	·00	11·6	(53)	13·3	(56)	15·5	(60)	3·8	(39)			General effluent	Clearer than No. 380.
385	11 ,,	3. p.m.	·00	·00	13·3	(56)	14·4	(58)	13·8	(57)	8·3	(47)			Screened sewage	A normal sample.
386	11 ,,	2. ,,	·00	·00	14·4	(58)	12·7	(55)	13·8	(57)	8·3	(47)			General effluent	Clear, slight yellow colour.
387	11 ,,	2.15 ,,	·00	·00	13·3	(56)	12·2	(54)	13·8	(57)	8·3	(47)			Final ,,	Clear.
388	11 ,,	2.30 ,,	·00	·00	13·3	(56)	13·3	(56)	13·8	(57)	8·3	(47)			,, ,,	Clear, no smell.
	1902:															
443	1 January	11 a.m. *Tuesday to 10 a.m. Wednesday.	—	·10	-	-	-	-	-		-	-	—	—	Screened sewage	24 hours sewage samples. *Heavy rain occurred early in the morning before the first sample was begun.
444	2 ,,	11 a.m. Wednesday to 10 a.m. Thursday.	·10	·00	-	-	-	-	-	-	-	-	—	—	,, ,,	
445	3 ,,	11 a.m. Thursday to 10 a.m. Friday.	·00	·00	-	-	-	-	-	-	-	-	—	—	,, ,,	
446	4 ,,	11 a.m. Friday to 10 a.m. Saturday.	·00	·14	-	-	-	-	-	-	-	-	—	—	,, ,,	
447	5 ,,	11 a.m. Saturday to 10 a.m. Sunday.	·14	·01	-	-	-	-	-	-	-	-	—	—	,, ,,	
448	6	11 a.m. Sunday to 10 a.m. Monday.	·01	·00	-	-	-	-	-	-	-	-	—	—	,, ,,	
449	7 ,,	11 a.m. Monday to 10 a.m. Tuesday.	·00	·00	-	-	-	-	-	-	-	-	—	—	,, ,,	

CROYDON SEWAGE FARM (BEDDINGTON).

TABLE II.

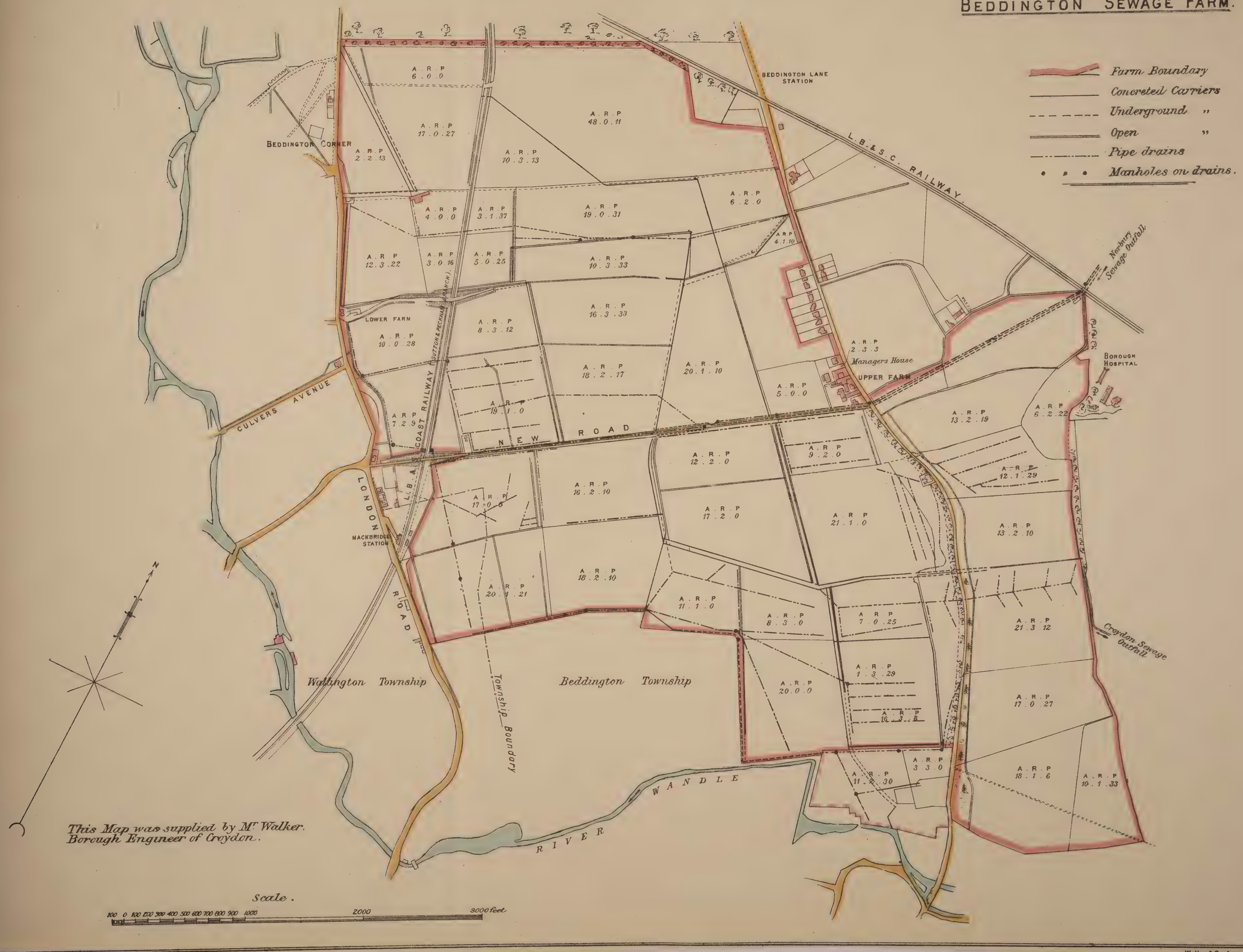
DOMESTIC SEWAGE.

EFFLUENTS.

Number of Sample.	Number of times the sewage is passed through or over the soil.	Area of plot or plots sewaged at the time of drawing Sample.	Length of time those plots had been sewaged previously to drawing Sample.	Nature of crops grown on plots.	REMARKS.
		Acres.	Days.		
37	Once	21·25	3*	Ryegrass - - -	Only fairly clear.
38	Twice	16·50	3	,, - - -	,, ,,
39	Three times	7·50	3	Permanent pasture -	Slight suspended matter.
41	Once	12·30 13·70	2	Ryegrass - - -	Cloudy effluent.
42	Twice	16·50	2	,, - - -	Fairly clear effluent.
43	Three times	7·50	2	Permanent pasture -	Very slight sewage smell.
150	Once	18·50	3	Ryegrass - - -	Effluent cloudy, sewage smell.
151	Twice	8·80	3	Permanent pasture -	Fairly clear, very slight sewage smell.
153	Twice	18·50 8·80	4	Ryegrass and permanent pasture.	Very slight sewage smell opalescent.
154	Three times	13·60 16·50 7·50	1	Ryegrass and permanent pasture.	Very slight sewage smell opalescent.
155	Three times	13·60 16·50 7·50	2	Ryegrass and permanent pasture.	Fairly clear, very faint sewage smell.
155a	Three times	8·75 18·75 17·0	1	Arable and ryegrass, permanent pasture.	No smell, clear.
156	Twice	21·25 16·50	3	Ryegrass - - -	Clear effluent.
175	Three times	20·0 18·75 17·0	1	Arable and ryegrass, permanent pasture.	No smell, and very clear, very little suspended matter.
159	Three times	13·60 18·75 17·0	2	Arable and ryegrass, permanent pasture.	No smell.
160	Three times	13·60 18·75 17·0	3	Arable and ryegrass, permanent pasture.	No smell, some suspended matter.
			EXPERIMENT:		
162	Once	4	1	Arable (freshly ploughed)	Filtration effluent.
163	Once	6	2	,, ,,	,, ,,
163a	Once	8	3	,, ,,	,, ,,
163b	Twice	8· & 1·	3	Arable and ryegrass -	Filtration effluent, very clear, no smell.
163c	Twice	9· & 1·5	4	,, ,, -	Filtration effluent, very clear, no smell.
163d	Once	11·	6	Arable only - - -	Filtration effluent.
164	Twice	11· & 2·	6	Arable and ryegrass -	,, ,,
164b	Once.	12·	8	Arable only - - -	,, ,,
165	Twice.	12· & 2·	8	,, - - -	,, ,,
166	Twice.	13· & 2·5	10	,, - - -	,, ,,
167a	Once.	13·5	11	,, - - -	,, ,,
167	Twice	13·5 & 2·10	11	,, - - -	,, ,,
168	Twice	15· & 2·25	13	,, - - -	,, ,,
169a	Once	15.	14	,, - - -	Filtration effluent, strong sewage smell, turbid.
169	Twice	15· & 2·25	14	,, - - -	Filtration effluent and surface effluent.
172	Twice	16· & 20·	17	,, - - -	Filtration effluent and surface effluent, no smell.
173	Twice	16· & 20·	18	,, - - -	Filtration effluent and surface effluent, no smell.
369	—	—	—	—	General effluent.
370	Three times	11·25 & 10· & 17·	1	Ryegrass - - -	Final ,,
371	Three times	11·25 & 10· & 7·5	1	,, - - -	,, ,,
374	Twice	13·50 & 17·	2	,, - - -	,, ,,
376	—	—	—	—	General ,,
378	Twice	13·50 & 17·	3	Ryegrass - - -	Final ,,
379	Twice	13·50 & 17·	3	,, - - -	,, ,,
380	—	—	—	—	General ,,
382	Three times	7·,10· & 20·25	1	Ryegrass - - -	Final ,,
383	Three times	7·,10· & 7·5	4	,, - - -	,, ,,
384	—	—	—	—	General
386	—	—	—	—	,, ,,
387	Three times	7·,10· & 20·25	2	Ryegrass - - -	Final ,,
388	Three times	7·,10· & 7·5	5	,, - - -	,, ,,

* The sewage is run on continuously both day and night.

Corporation of Croydon
Beddington Sewage Farm.



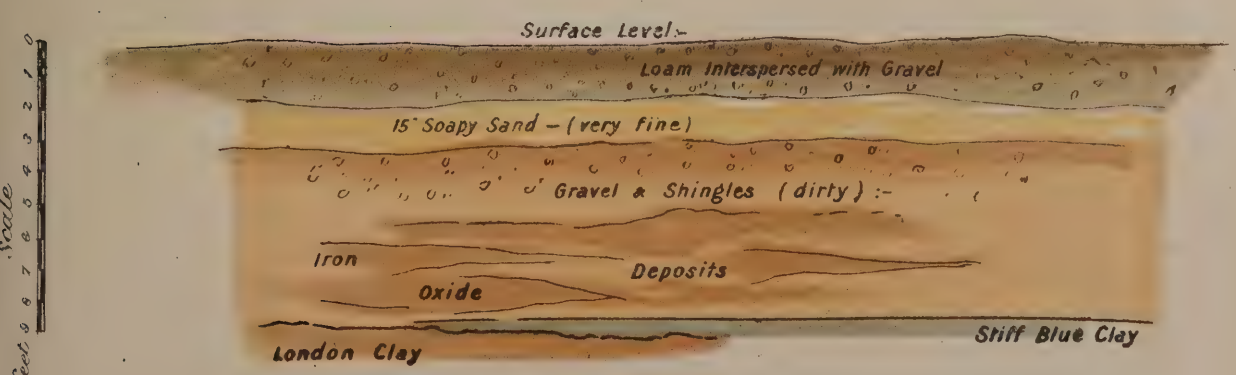
Weller & Graham Ltd Litho. London.

CROYDON SEWAGE FARM.

Scale:-12 Inches to a Mile.

RIVER SAMPLES.

SECTION AT BEDDINGTON SEWAGE FARM, CROYDON.

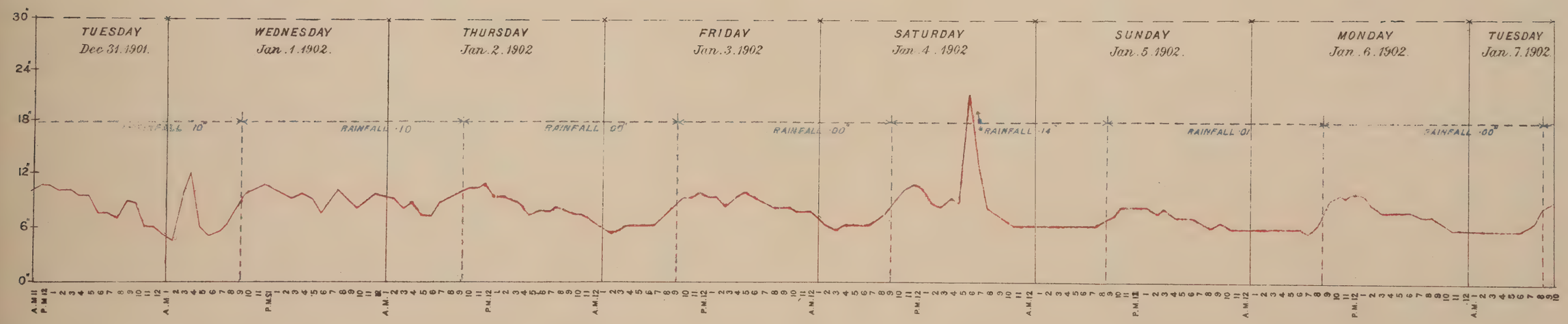


Weller & Graham Ltd Litho. London.

Addendum B.
III.

CROYDON SEWAGE.

Diagram Shewing hourly height of sewage in the main Carrier.

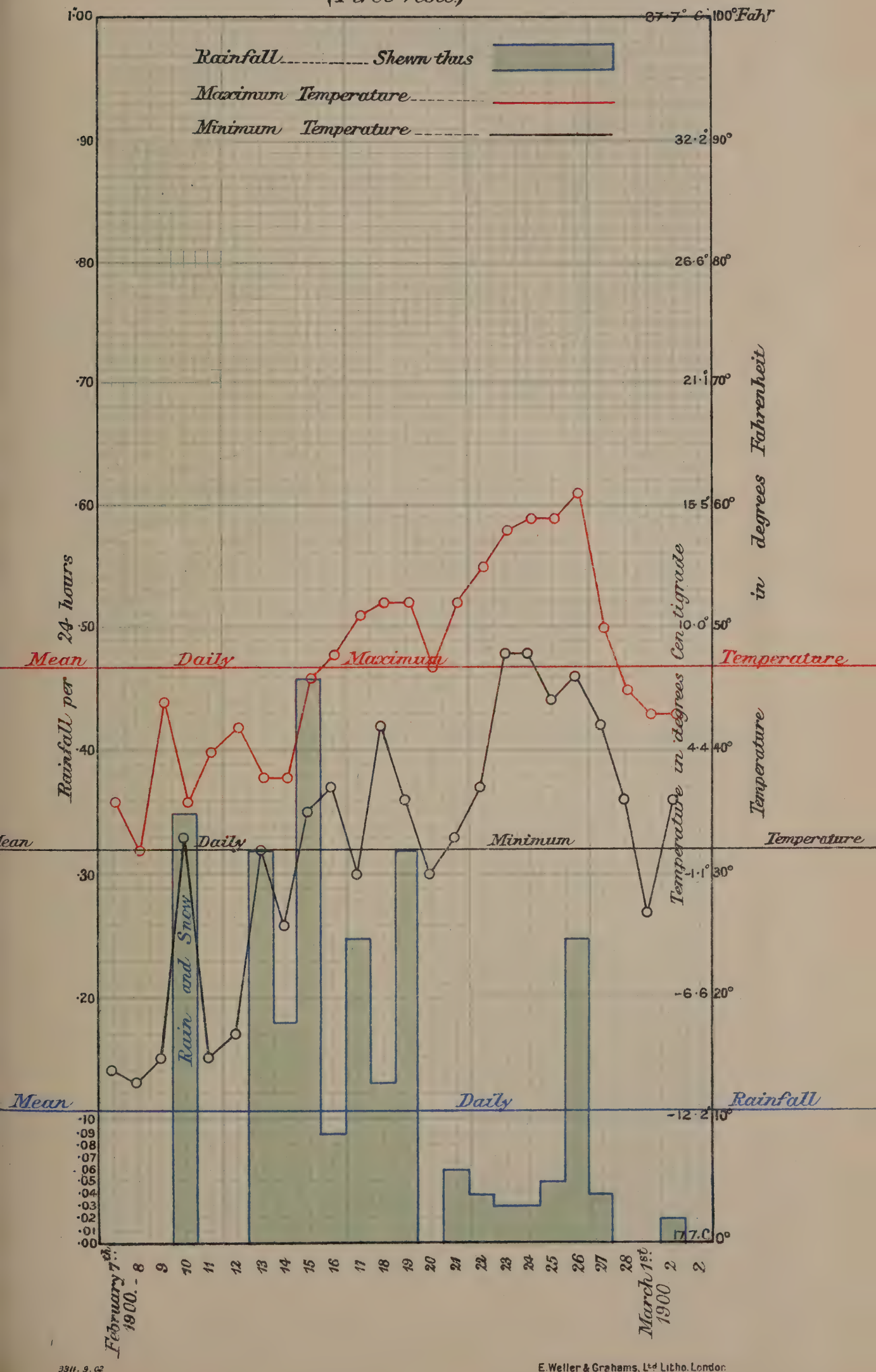


3311. 9. 02.

Weller & Graham Ltd Litho. London.

CROYDON (BEDDINGTON) SEWAGE FARM.

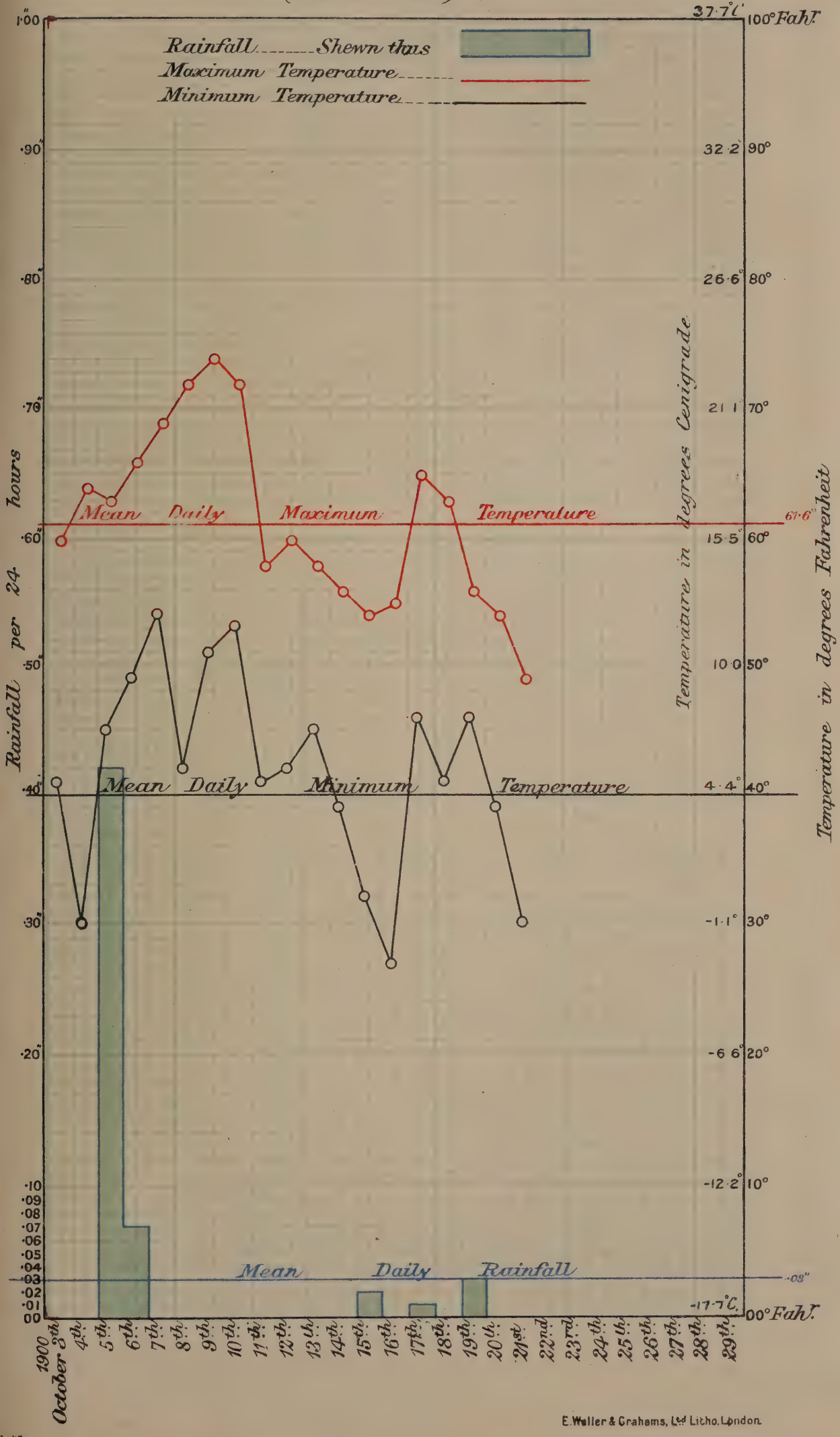
(First Visit.)



3311. 9. 02
E. Weller & Grahams, Ltd Litho. London

CROYDON (BEDDINGTON) SEWAGE FARM.

(Second Visit)



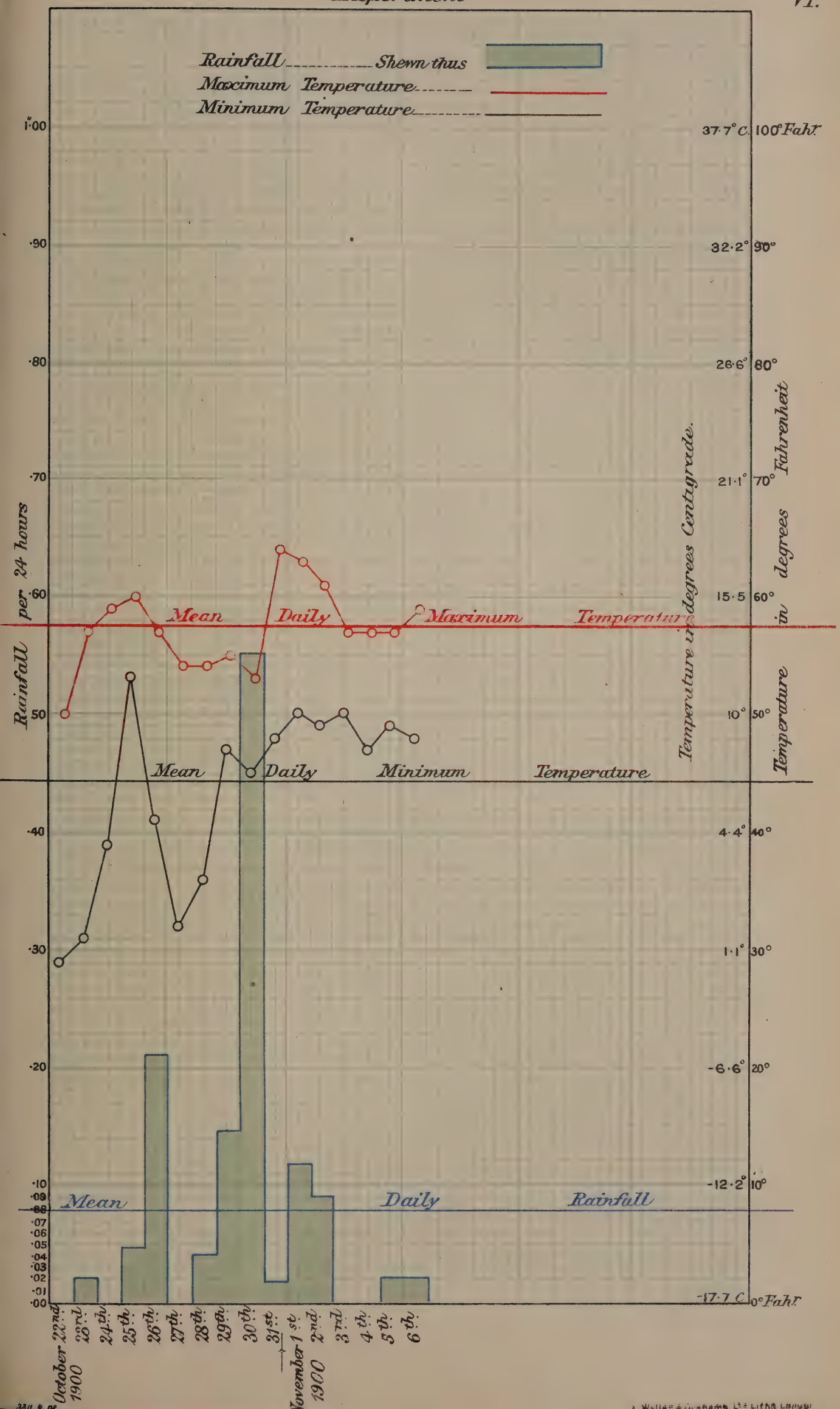
E. Weller & Grahams, Ltd Litho. London.

CROYDON (BEDDINGTON) SEWAGE FARM

Experiment

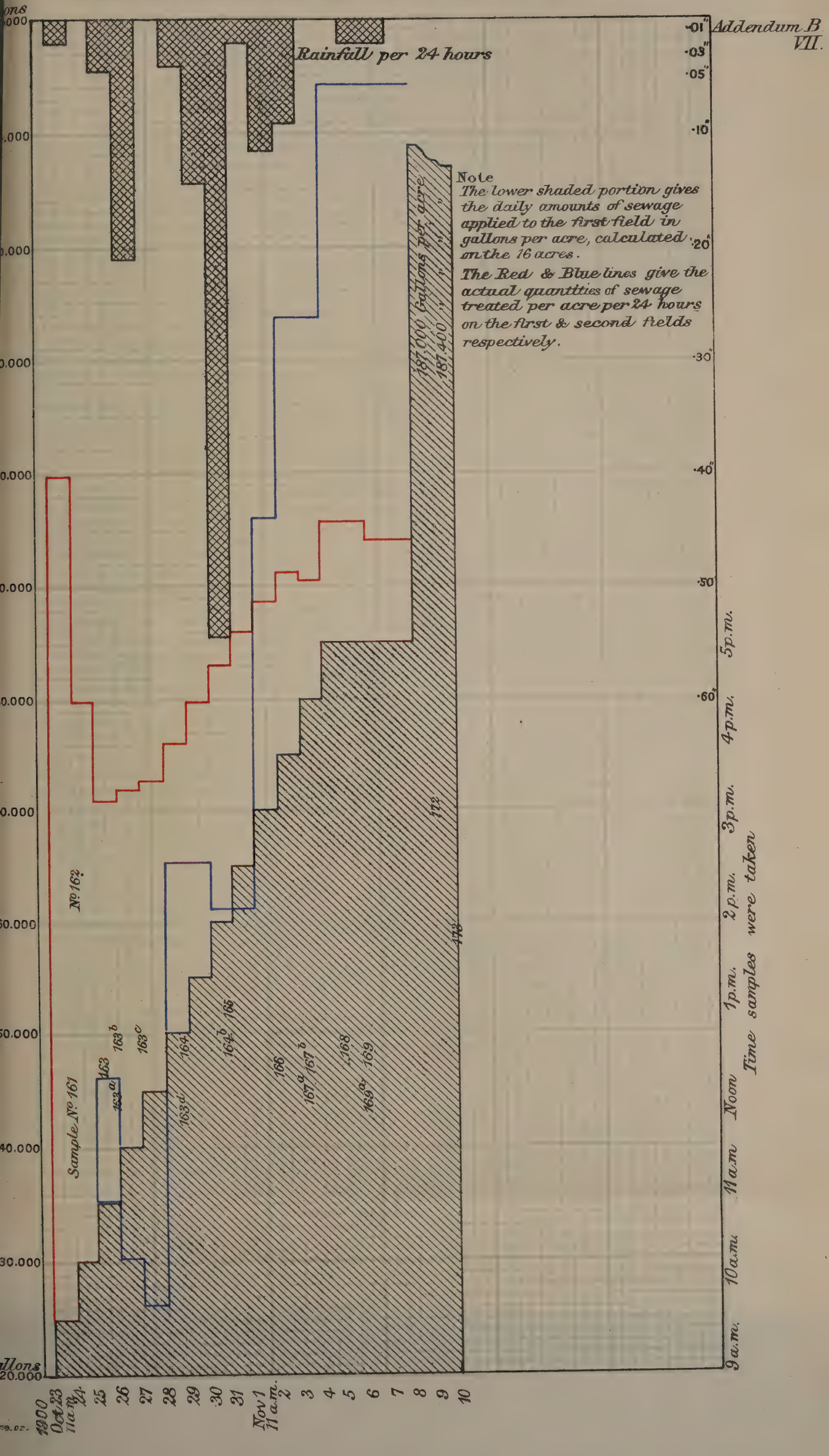
Addendum B.

VI.



L. Weller & Grahams, Ltd Litho. London

CROYDON (BEDDINGTON) SEWAGE FARM. *(Experiment)*



CROYDON SEWAGE FARM (BEDDINGTON).

TABLE III.

(Domestic Sewage.)

* Comparative Samples or Samples taken from the same plots of land.

Field Effluents.	2nd Field Effluents.	3rd Field or Final Effluents.	Remarks.
{150, 153}	{151, 153}	{154, 155}	*By comparative samples is meant samples drawn from the same areas of land, and the effluents in brackets are comparable with each other so far as the area of land sewaged is concerned.
	{374, 378, 379}	{159, 160}	
	{172, 173}	{382, 387}	
		{383, 388}	

TABLE IV.

Sewage Samples.

Number of Sample.	Nature of Sewage.	Time taken.	Remarks.
36	Screened sewage -	12.15 p.m. - - - - - -	Sewage rather dilute from melting snow.
40	,, ,, -	11.45 a.m. - - - - - -	Sewage rather dilute from rain.
149	Screened and settled sewage.	11.45 a.m. - - - - - -	Norbury sewage, about normal.
152	Screened and settled sewage.	11 a.m. - - - - - - -	Sewage appeared coagulated.
158	Screened sewage -	12 (noon) - - - - - - -	Rather dilute and soapy.
161	,, ,, -	12.15 p.m. - - - - - -	Sewage fairly strong and very soapy.
164a	,, ,, -	11.30 a.m. - - - - - -	Sewage apparently about normal.
372	,, ,, -	2 p.m. - - - - - - -	Somewhat dilute owing to rain.
373	,, ,, -	11.45 a.m. - - - - - -	,, ,, ,,
377	,, ,, -	10.30 a.m. - - - - - -	,, ,, ,,
381	,, ,, -	10.45 a.m. - - - - - -	Sewage about normal.
385	,, ,, -	3 p.m. - - - - - - -	,, ,,
		24 hours' sewage samples:	
443	Screened sewage -	11 a.m. Tuesday to 10 a.m. Wednesday	These samples were taken from the main carrier on the farm, after screening, the sewage being in the same condition in which it is applied to the land.
444	,, ,, -	11 a.m. Wednesday to 10 a.m. Thursday	
445	,, ,, -	11 a.m. Thursday to 10 a.m. Friday	
446	,, ,, -	11 a.m. Friday to 10 a.m. Saturday	
447	,, ,, -	11 a.m. Saturday to 10 a.m. Sunday	
448	,, ,, -	11 a.m. Sunday to 10 a.m. Monday	
449	,, ,, -	11 a.m. Monday to 10 a.m. Tuesday	

CAMBRIDGE SEWAGE FARM.

(Cambridge Corporation.)

1. Situation of farm.—On the Milton Road about 3 miles from Cambridge.

2. Total acreage of farm.—102·5 acres.

3. Total irrigable area.—74 acres.

4. Average area irrigated at one time.—18·5 acres.

5. Population draining to farm.—50,000.

6. Population per acre irrigated.—675.

7. Gallons of sewage per head, per day.—45.

8. Dry weather flow of sewage, per 24 hours.—2,250,000 gallons.

9. Gallons of sewage (exclusive of storm water) treated per acre, per 24 hours.—121,600 = $\left(\frac{2,250,000}{18 \cdot 5}\right)$.

10. Gallons of sewage treated per acre, per 24 hours, on the assumption that each acre of irrigable area is under sewage all the time. (This for purposes of comparison $\left(\frac{2,250,000}{74}\right)$ = 30,400 gallons.

11. Characters of the sewage.—Mainly domestic (some brewery effluent).

12. Method of treatment.—Screening, settling tanks, and land filtration.

13. General characters of the soil and subsoil.—Sandy loam overlying gravel and sand.

14. Separate or combined sewerage system.—Partially separate.

15. The final effluent is discharged into.—River Cam.

16. Number of years farm in operation before 1900.—5 years (systematic working).

CAMBRIDGE SEWAGE FARM REPORT.

SUMMARY OF CONTENTS.

DESCRIPTION OF FARM.

Addendum A.—Notes on Samples.

Table I.—Shewing all samples drawn at the Cambridge sewage farm, together with time of drawing, rainfall, temperatures, description of sample, etc.

Table II.—Giving area of plots from which effluents were drawn, and the time those plots had been under sewage, etc.

Table III.—Corresponding effluents.

Table IV.—Sewage samples.

Table V.—Comparative effluents.

Additional notes on samples.

Addendum B.—Plans and diagrams referred to in report.

I.—Plan of farm.

II.—Section of soil and subsoil.

III.—Diagrams shewing hourly variations in depth of sewage passing over tank cill during 48 hours.

IV.—Diagrammatic plan and section, shewing plots under sewage.

V.—Detail of carrier sewage outlets.

IV.—Plan and section of effluent manhole.

VII.—Plan referring to river samples.

VIII.—Temperature, rainfall, and humidity chart.

CAMBRIDGE SEWAGE FARM.

Cambridge Corporation.

(Domestic Sewage, with a small amount of Brewery effluent.)

The soil on this farm is gravel and sand, and the sewage which (with the exception of a small quantity of effluent from two breweries) is domestic, is treated by screening, settling tanks, and land filtration.

The surface soil on the farm is composed of 12 inches to 15 inches sandy loam, overlying a somewhat compact stratum of gravel and sand, the gault clay lying at a depth of from 7 feet to 12 feet from the ground level. (Add. B. II.) About 2 feet to 2 feet 6 inches from the surface soil, a vein of sand impregnated with iron occurs in parts. The subsoil water in dry weather lies at a depth of 6 feet to 7 feet from the ground level.

The present farm has been systematically in operation for sewage treatment since 1895 and is managed by the Cambridge Corporation.

It is not liable to floods.

The normal dry weather sewage flow is 2,250,000 gallons, or about 45 gallons per head of the population draining to the farm, but about 40 per cent. of this is subsoil water due to faulty sewers. After heavy storms the sewage flow sometimes does not return to normal for some days, in consequence of the excess of subsoil water finding its way into the sewers.

The districts draining to the sewage farm are Cambridge and Chesterton, with a combined population of 50,000.

The area served by the sewers is about 1,500 acres, or 33·3 persons per acre. The water supply is about 24 gallons per head, obtained from wells in the chalk marl, greensand, and the chalk. There are a very few privies in the borough, and from these farmers fetch the night soil. The town is only partially on the separate system. All water from back-yards and roofs (back parts of) goes to the foul water sewers. The streets are principally macadam. The average annual rainfall at Cambridge for the past 36 years (1865–1900) is 21·02 inches.

The sewers are flushed quarterly with waterworks water. The whole of the sewage gravitates to the pumping station through a 4 ft. 3 in. by 2 ft. 10 in. sewer laid at a gradient of about 1 in 870, its theoretical capacity running full being 2,060 cubic feet a minute. The sewage takes about one hour to flow from the centre of Cambridge to the pumping station, a distance of $1\frac{1}{4}$ miles.

There are five storm overflows discharging into the Cam on either side of the pumping station; they have only once come into operation during the last eight years; the sewage has to rise about 30 feet in the pump well before an overflow takes place, and this would back up the water in the outfall sewer, flooding some portions of the town. Up to 5,000,000 gallons of sewage and storm water per 24 hours, *i.e.*, a little more than twice the dry weather flow, have been dealt with by the pumps. Formerly during heavy storms, when the ground was already saturated, the storm water and sewage were pumped direct into the river. Now, however, all the storm water is treated on coarse clinker beds at the pumping station before passing into the river, consequently the amount received at the farm during storms is not greatly in excess of the normal flow, except that, as previously stated, the after effect of the storm is felt by the increased subsoil leakage.

On arrival at the pumping station, the sewage, after having first passed through a cage screen, flows into the pump well. The screenings are burnt in the destructor.

The pumping plant consists of two 80 h.p. tandem condensing engines, worked alternately for a normal sewage flow, each engine lifting 275 gallons per stroke. A 6-cell destructor is used for disposing of the town's refuse, and at the same time for supplying steam for pumping purposes.

From the pumping station the sewage is pumped to the farm along a 24-inch cast-iron rising main 2 miles long, the sewage taking about 40 minutes to reach the settling tank from the pumping station. The lift is 44 feet.

The sewage on reaching the farm passes through the old lime-mixing

house (disused) and into the settling tank, which has been constructed from a maze, formerly used to incorporate the lime with the sewage.

It will be advisable at this point to shortly explain this reference to lime treatment, as it has an important bearing on the history of the farm. The lime process was used for 2½ years (commencing 1895), lime being added at a rate first of all of 15 grains per gallon, subsequently this amount was reduced to 11, 10, and finally 8 grains of lime per gallon; this treatment was, however, eventually abandoned in November, 1898, as it was found that the farm was rapidly becoming choked for filtration purposes. Since November, 1898, no chemicals whatever have been employed.

There is only one settling tank, 61 feet by 39 feet by about 3 feet (average depth), with a capacity of about 45,000 gallons; or only about 2 per cent. of the dry weather flow per 24 hours. (Add. B. III.) It is worked on the continuous system. This tank is cleaned out twice a week, the operation only taking about half an hour.

The sludge is run into oblong sludge bays laying alongside of the carrier embankments, into which it is subsequently dug. It is also run over other portions of land where wanted, being kept off the area irrigated as much as possible. When lightly buried the sludge disappears in about six months. Approximately 35 tons, on an average, of wet sludge, are produced per week, but the quantity varies considerably.

The sewage after settlement in the tank flows along the main carrier running down the centre of the farm, this carrier being formed of blue bricks and with half-pipe invert, in embankment. (Add. B. V.)

The secondary carriers are similarly constructed and branch at right angles from the main carrier on either side, extending along the top side of the plots irrigated. The settled sewage passes from the secondary carriers through sluices on to the land to be sewaged. The maximum and strongest sewage flow at the farm takes place between 11 a.m. and 2 p.m.

The total capital outlay on the sewage farm up to the present date (1901) has been £23,000.

The total acreage of the farm is 102·5 acres. (Add. B. I.) The area actually irrigated is 74 acres, exclusive of an additional filtration area now being prepared. The whole 74 acres sewaged are arable. This area (74 acres) takes (excluding the question of storm water) 2¼ million gallons during the 24 hours. With a population of 50,000 persons this is equal to 675·67 persons per acre of irrigable area, or 30,400 gallons per acre (at 45 gallons of sewage per head). Approximately one-fourth of the total irrigable area is irrigated at one time, so that 121,600 gallons of sewage are treated per acre per 24 hours. The farm is laid out in plots of a convenient size ranging from about 3 to 6 acres each, and thay are laid out perfectly level, the carrier embankments forming an enclosure on three sides and the remaining side being banked up or fendered to retain the sewage which is only treated once through the land. (Add. B. IV).

The practice followed in irrigating, is to flood the sewage on to the plots from the carrier outlets, running it on continuously night and day for about four days to a week, the plots then being allowed to dry as long as possible. In the case of two fields (Nos. 4 and 11) which are used as natural filter beds, manholes and penstocks are provided by means of which the sewage can be held in contact with the soil for some hours. (Add B. VI.) These plots are sewaged continuously for about six hours a day.

Some plots which have been sewaged longer than others will not pass so much sewage owing to the scum formed on the surface, and therefore the sewage has to be shut off sooner from them, and other plots with less scum receive the surplus sewage. The surface scum has a beneficial effect, by checking filtration when the plot is becoming sludged up and so preventing the land from becoming sewage sick. When the land is sufficiently dry to admit of it, a light spring scarifier has been found of great assistance in breaking up this surface skin of sludge. Occasionally a "stank"* is used and only a portion of a plot utilised for sewage.

* By "stank" is meant a small embankment or "fender," to retain the sewage within certain limits.

The entire farm is underdrained, chiefly 50 feet apart, and at a depth of from 3 feet 6 inches to 6 feet. On two plots, however (Nos. 4 and 11), the drains are only 16½ feet and 14 feet apart respectively, with the view of increasing the rate of filtration. The feeder drains are ordinary 4-inch butt land-tiles, connected up to 12-inch, 18-inch and 21-inch socketted stoneware master drains, which in turn are connected to a 24-inch main effluent outfall. The drains are chiefly laid herringbone fashion, and the filling above the drains on the greater portion of the farm consists of the soil excavated. Some of the plots of the lower part of the farm have air vents to the underdrains brought up to the ground level. As these are only brought up to slightly above ground level and not carried any distance above it, there is a danger of storms or other circumstances causing the sewage to flow from the surface of the plots directly down these air vents to the drains. In the case of the two closely-drained plots previously mentioned, the top 18 inches of the drain trench has been filled up with destructor clinker, and about 100 tons of fine destructor ash were ploughed into the soil of one plot (No. 4 on plan). This plot, which is next to the liming house, received the greatest quantity of sludge during the time when chemicals were used, and in addition some sludge had been carted and dug into this land forming an almost* impervious stratum in one part of the field, and the ashes were put in with the object of remedying this. There is very little smell arising from the sewaging operations.

Very few crops are grown on the farm. Those grown are kohl rabbi, mangolds, and horse corn, and they are sold. A large portion of the farm is always uncropped, *i.e.*, the soil is mainly used as a bacterial filter, and therefore in this respect the farm differs from the Nottingham Sewage Farm.

There is no profit on the farm.

The cost of 1,000,000 gallons of sewage treated is :—

	£	*s.*	*d.*	
(a) Pumping - - - -	1	9	7	(including the destructor).
(b) Net cost of treatment on farm	1	0	1	
Total - -	2	9	8	

The total working cost (from Lady-day, 1899–1900) to Cambridge and Chesterton for pumping and sewage treatment was £2,500 (destructor included), or under 2*d.* in the £ on the assessable value of these places.

There is one main effluent outfall discharging into the River Cam a short distance below Baitsbite Lock. The river at this point has a normal volume of about 30,000,000 gallons per 24 hours, and a very slow current ; it appeared to be in good condition. The volume of effluent as compared to the volume of the river is about as 1 to 15 normally. A small quantity of sewage fungus was noticeable at times issuing from the main effluent outfall, which has a submerged outlet.

At the time of the last visit to the Cambridge Sewage Farm some barges were being loaded with a quantity of gas lime from the gas works which are situated close to the sewage pumping station, and a considerable quantity of this lime was lying on the river bed at this point.

The farm appears to be very well managed.

The chief difficulty in working the farm is to keep the top soil loosened, as it cannot always be ploughed in the winter. After ploughing, subsoiling with a scarifier has been found of great assistance. During summer the land is kept ploughed as frequently as possible.

The effluent does not appear to vary much in character.

Notes on Temperature, Rainfall, etc.

During the visit to the Cambridge sewage farm (7th January to 6th February, 1901)—the temperatures were about the average for the time of year. Snow fell on five days, but not in any great quantity, whilst the rainfall was slight, with the exception of 27th January, when ·22in. was recorded. Several frosts occurred, freezing the sewage standing on the plots.—(See Add. B. VIII.).

* Some of this sludge, after having been buried about 18 inches deep for five years, resembled a dense black clay.

TABLE I.

Domestic Sewage.

Number of Sample.	Date of drawing Sample.	Time of day.	Rainfall day previous to drawing Sample.	Rainfall day of drawing Sample.	Air Temperature time of drawing Sample.	Temperature of Sample.	Maximum Temperature during the 24 hours.	Minimum Temperature during the 24 hours.	Humidity 9 a.m.	Dissolved Oxygen in Sample.	Brief description of Sample.	Remarks
	1901:		Inches.	Inches.	°C. °F.	°C. °F.	°C. °F.	°C. °F.		c.cs.		
201	8 January -	12.20 p.m.	·00	·01 (snow)	·5 (33)	6·6 (44)	0·0 (32)	−5·5 (22)	—	—	Sewage.	Mean daily maximum temperature 5·1° C. (41·3° F.)
202	8 „ -	1.30 p.m.	·00	·01	2·2 (36)	6·1 (43)	0·0 (32)	−5·5 (22)	—	3 75	Effluent.	Mean daily minimum temperature ·4° C. 32·7° F.
203	9 „ -	11.25 a.m.	·01 (snow)	·08 (snow)	0·0 (32)	5·5 (42)	3·8 (39)	0·0 (32)	—	·75	„	
204	9 „ -	12.15 p.m.	·01 (snow)	·08	0·0 (32)	5·5 (42)	3·8 (39)	0·0 (32)	—	1·25	§General effluent.	Mean daily humidity 86·7.
205	10 „ -	11.45 a.m.	·08 (snow)	·01	5·5 (42)	4·4 (40)	9·4 (49)	·5 (33)	92	6·25	„ „	Mean daily rainfall ·021 inches.
205A	10 „ -	12 (noon)	·08 (snow)	·01	5·5 (42)	5· (41)	9·4 (49)	·5 (33)	92	1·50	River water.	For the period 7th January 1901 to 6th February 1901.
205B	12 „ -	11.15 a.m.	·00	·00	5· (41)	10· (50)	10· (50)	3·3 (38)	95	—	Sewage.	
205C	12 „ -	12.20 p.m.	·00	·00	5· (41)	5·5 (42)	10· (50)	3·3 (38)	95	1·00	Effluent.	
207	14 „ -	11.30 a.m.	·00	·00	5·5 (42)	5· (41)	5· (41)	−2·7 (27)	76	2·50	General effluent.	*Note.*—Samples which may have been affected by rainfall or snow are underlined.
208	15 „ -	11.15 a.m.	·00	·00	1·6 (35)	5· (41)	3·3 (38)	2·2 (36)	90	2·75	„ „	
209	16 „ -	11.40 a.m.	·00	·00	4·4 (40)	4·4 (40)	9·4 (49)	4·4 (40)	91	2·00	„ „	
209A	16 „ -	12 (noon)	·00	·00	4·4 (40)	2·2 (36)	9·4 (49)	4·4 (40)	91	7·00	River water.	
210	16 „ -	12.30 p.m.	·00	·00	5· (41)	5·5 (42)	9·4 (49)	4·4 (40)	91	3·75	Effluent.	§ By "General" effluent is meant a mixture of two or more finally treated effluents on leaving the farm.
210A	18 „ -	2.40 p.m.	·09	·03	7·2 (45)	6·1 (43)	7·2 (45)	7·2 (45)	93	3·00	„	
211	21 „ -	1.45 p.m.	·00	00	11·1 (52)	6·6 (44)	11·1 (52)	7·7 (46)	93	4·00	„	
212	21 „ -	4.45 p.m.	·00	·00	10·5 (51)	5·5 (42)	11·1 (52)	7·7 (46)	93	1·25	„	
213	23 „ -	11.15 a.m.	·00	·00	5·5 (42)	10· (50)	5·5 (42)	0·0 (32)	98	—	Sewage.	
214A	23 „ -	12.30 p.m.	·00	·00	5·5 (42)	5·5 (42)	5·5 (42)	0·0 (32)	98	6·	River water and effluent.	
214	23 „ -	1.15 p.m.	·00	·00	6·1 (43)	5·5 (42)	5·5 (42)	0·0 (32)	98	·50	General effluent.	
214B	26 „ -	12.45 p.m.	·03	·00	5·5 (42)	5·5 (42)	4·4 (40)	1·1 (34)	77	1·25	„ „	
215	28 „ -	11.15 a.m.	·22	·02 (snow)	2·2 (36)	10· (50)	1·1 (34)	−1·1 (30)	91	—	Sewage.	
216	28 „ -	12.50 p.m.	·22	·02 (snow)	3·3 (38)	6·1 (43)	1·1 (34)	−1·1 (30)	91	1·50	Effluent.	
217	28 „ -	2.30 p.m.	·22	·02 (snow)	3·3 (38)	10· (50)	1·1 (34)	−1·1 (30)	91	—	Sewage.	
218	28 „ -	4.0 p.m.	·22	·02 (snow)	·5 (33)	6·1 (43)	1·1 (34)	−1·1 (30)	91	2·75	Effluent.	
219	30 „ -	11.30 a.m.	·01 (snow)	·00	2·2 (36)	6·6 (44)	2·2 (36)	−2·2 (28)	91	3·50	Subsoil water.	
220	4 February -	12.15 p.m.	·00	·05 (snow)	0·0 (32)	4·4 (40)	·5 (33)	−1·6 (29)	89	·25	General effluent.	

TABLE I.—DOMESTIC SEWAGE—*continued.*

Number of Sample.	Date of drawing Sample.	Time of day.	Rainfall day previous to drawing Sample.	Rainfall day of drawing Sample.	Air Temperature time of drawing Sample.	Temperature of Sample.	Maximum Temperature during the 24 hours.	Minimum Temperature during the 24 hours.	Humidity 9 a.m.	Dissolved Oxygen in Sample.	Brief description of Sample.	REMARKS.
	1901:		Inches.	Inches.	°C. °F.	°C. °F.	°C °F	°C °F		c.cs.		
221	5 February -	11.30 a.m.	·05 (snow)	·05 (snow)	1·1 (34)	4·4 (40)	2·2 (36)	−1·1 (30)	98	·50	General effluent.	
222	6 „ -	12 (noon)	·05 (snow)	·00	2·2 (36)	1·1 (34)	2·7 (37)	0·0 (32)	95	7·00	River water.	
223	6 „ -	12.15 p.m.	·05	·00	2·7 (37)	1·1 (34)	2·7 (37)	0·0 (32)	95	5·50	River water and effluent.	
	1902:											
475	25 February -	Noon Mon. to 11 a.m. Tues.	·08	·19	—	—	—	—	—	—	Screened and settled sewage.	24 hours samples.
476	26 „ -	Noon Tues. to 11 a.m. Wed.	·19	·00	—	—	—	—	—	—	Screened and settled sewage.	
477	27 „ -	Noon Wed. to 11 a.m. Thurs.	·00	·10	—	—	—	—	—	—	Screened and settled sewage.	

CAMBRIDGE SEWAGE FARM.

TABLE II.—EFFLUENTS.

Number of Sample.	Number of times treated.	Area of plot or plots sewaged.	Period sewaged previously to drawing Sample.	Nature of crops grown on plots.	Remarks.
		A. R. P.			
202	Once	*4 3 22	4½ hours.	None.	*This plot was last sewaged on 2nd January 1901.
203	„	4 3 22	26 hours.	„	on surface of plot.
204	„	About 20 acres.	Various periods.	„	General effluent.
205	„	„ „	„ „	„	„ „
205C	„	4 3 22	24 hours.	„	
207	„	—	Various periods.	„	General effluent.
208	„	—	„ „	„	„ „
209	„	—	„ „	„	„ „
210	„	4 3 22	3½ hours.	„	
210A	„	4 3 22	6 „	„	
211	„	4 3 22	4¾ „	„	
212	„	4 3 22	7¾ „	„	
214	„	—	Various periods.	„	General effluent.
214B	„	—	„ „	„	„ „
216	„	4 3 22	4 hours.	„	
218	„	4 3 22	7 „	„	
220	„	...	Various periods.	„	General effluent.

TABLE III.

* Corresponding Effluents.

Number of Samples.	Remarks.
Samples Nos.— 201 and 202 205B and 205C 215 and 216 213 and 214 217 and 218	* *i.e.*, Effluents corresponding to screened or settled sewage in each case: that is to say, that the effluent is taken some time after the sewage sample, to show as far as possible the degree of purification effected on that particular sewage.

TABLE IV.

Sewage Samples.

Domestic Sewage, with a small amount of Brewery effluent.

Number of Sample.	Nature of Sewage.	Character.	Time taken.	Remarks.
201	Screened sewage - - -	—	12.20 p.m.	Taken before passing through settling tank.
205B	Screened and settled sewage -	Very weak -	11.15 a.m.	„ after „ „ „
213	„ „ „	Very dilute -	11.15 a,m.	„ „ „ „ „
215	„ „ „	„ „ -	11.15 a.m.	„ „ „ „ „
217	„ „ ,	Fairly strong -	2.30 p.m.	„ „ „ „ „

TABLE V.

* Comparative Samples, or samples taken from the same plots of land

Number of Samples.	Remarks.
No. 202 „ 203 „ 205C „ 210 „ 211 „ 212 „ 216 , 218	*By comparative samples is meant samples drawn from the same areas of land, and the effluents in brackets are comparable with each other so far as the area of land is concerned.

Additional NOTES on Different Samples.

No. 201. Screened sewage not having passed through the settling tank, *i.e.*, only roughly screened at the pumping station before being pumped : a weak sample, apparently containing a large quantity of subsoil water.

No. 202. Corresponding final effluent to sewage No. 201 : sample appeared very fairly clear and had a very faint smell on shaking.

No. 203. The final effluent was from the same plot as No. 202 and was from a very dilute sewage ; the plot was covered with a sheet of ice. The sewage had been applied continuously for 28 hours. The sample was clear and had a very slight smell. Heavy snow (·08 inch melted) fell during the day, diluting the sewage.

No. 204. General effluent : fairly clear, very slight smell, some suspended matter, probably affected by the snow (·08 inch) during the day.

No. 205. General effluent : as No. 204, but hardly so clear.

No. 205A. River Cam water taken above the effluent outfall, river slightly above the normal height a clear sample, river apparently in fair condition.

No. 205B. Screened and settled sewage : very dilute, a large amount of grease coming down.

No. 205C. Corresponding final effluent to No. 205B ; ice disappeared from plot irrigated.

No. 207. General effluent : slight iron smell, some flocculent red matter (sewage weed disintegrated ? probably washed from drains by increase of effluent following rainfall.

No. 208. General effluent : slight iron smell on shaking. This is apparently a fair average sample of the general effluent for the time of year.

No. 209. General effluent : some fragments of sewage weed, rather cloudy. Some of the plots becoming rather thickly coated with sludge on the surface.

No. 209A. River water drawn above effluent outfall, river normal : a clear sample, and apparently well oxygenated.

*No. 210. Final effluent : clear, no smell ; plot with an average coating of sludge $\frac{3}{8}$ inch thick (after 10 days' intermittent sewaging).

No. 210A. Final effluent : clear, no smell ; the sewage going on to the plot was much stronger than usual, and of a dark brown colour.

No. 211. Final effluent : drawn when the effluent was running freely away from the drains.

No. 212. Final effluent : as above, but after being held in contact with the land for $2\frac{1}{4}$ hours. The sewage running on to the plot sewaged was, however, apparently stronger from 1 p.m. to 2 p.m. than from 11 a.m. to 12.30 p.m.

No. 213. Screened and settled sewage : dilute.

No. 214. General effluent : suspended matter, very slight smell.

No. 214B. River water taken 100 yards below effluent outfall, river normal height : 6 ccs. oxygen in sample taken immediately below outfall ; 6·50 ccs. 90 yards further down stream. A fairly clear sample.

No. 214B. General effluent : slightly cloudy, slight smell, some plots requiring a rest.

No. 215. Screened and settled sewage : weak.

No. 216. Final effluent : clear, no smell.

No. 217. Screened and settled sewage (strong) taken later in the day than previous samples to shew the hourly variations in strength.

No. 218. Final effluent : clear, no smell, hardly any suspended matter.

No. 219. Subsoil water taken from a land drain at the outcrop of the gault in a field in the neighbourhood of the farm, but which was not in such a position as to be affected by the sewage farm : apparently pure, no suspended matter, bright and sparkling.

No. 220. Genral effluent : cloudy, slight smell.

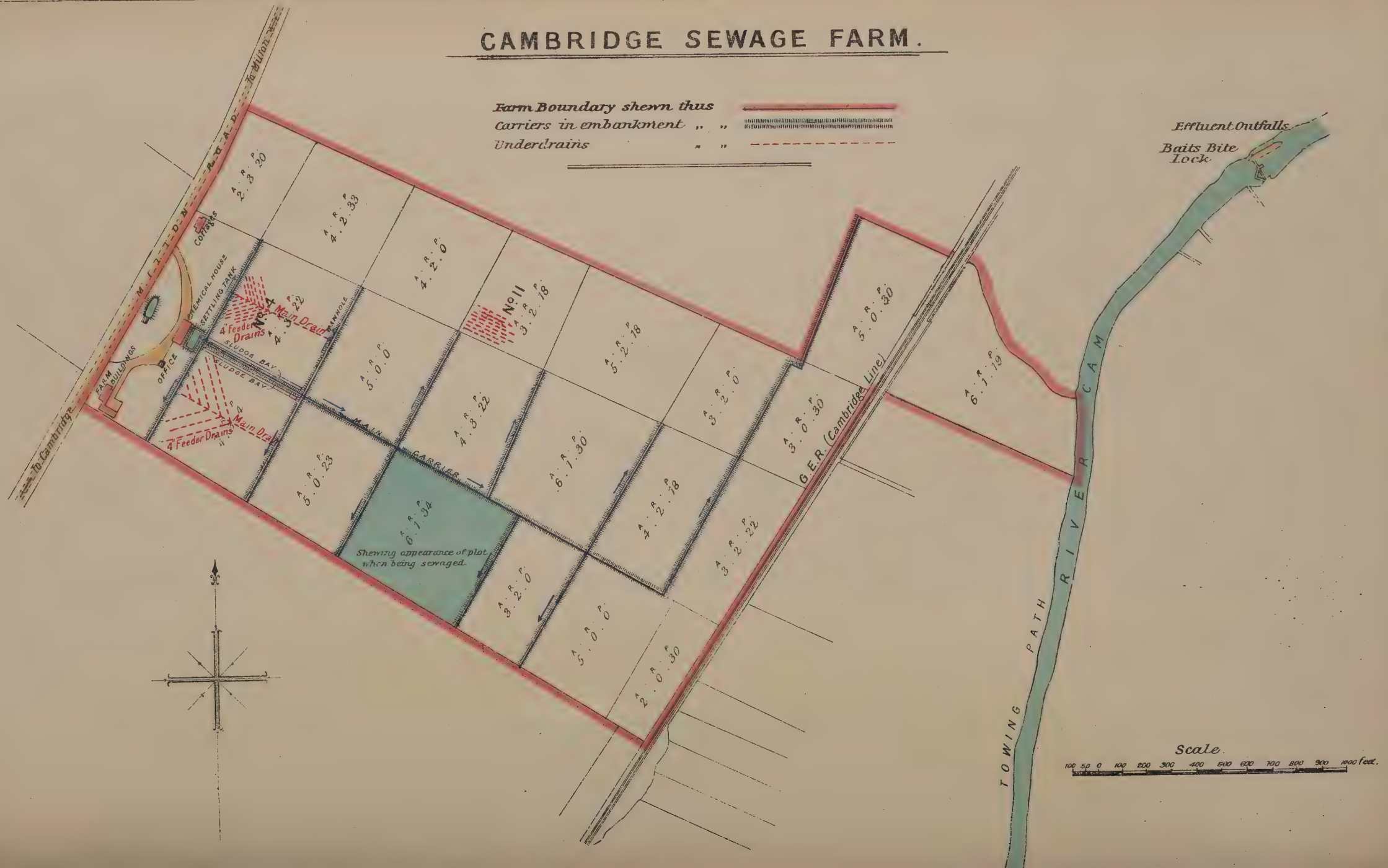
No. 221 General effluent : very cloudy, strong sewage smell, apparently worst effluent drawn from farm, snow (·05 inch) stirred up silt from surface of plots at bottom of farm.

No 222. River water taken above effluent outfall, river normal (Add. B. vii.) : 7 ccs. by oxygen test.

No. 223. River water and effluent taken 10 yards below effluent outfall : 5·50 ccs. by oxygen test.

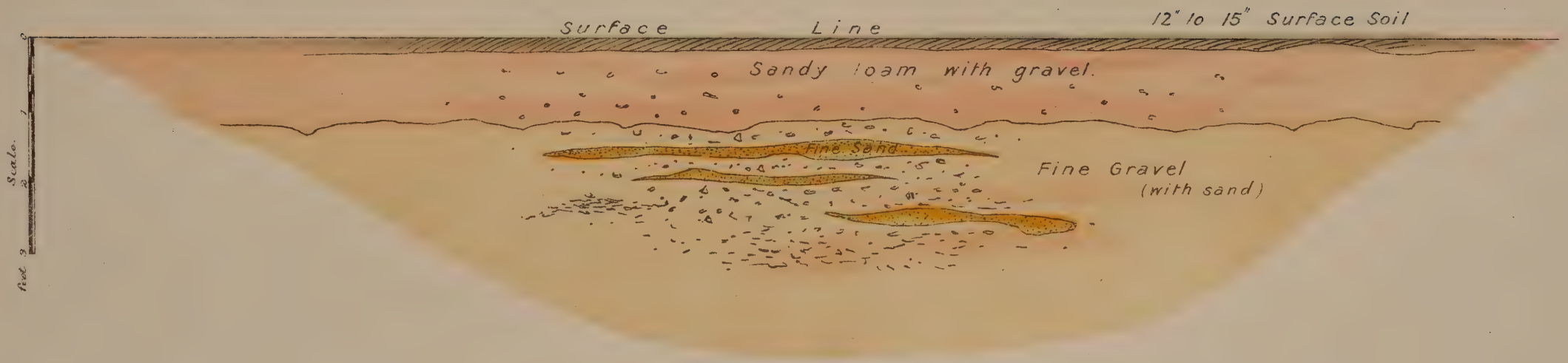
* This coating of sludge seemingly acts as the "felt" on the surface of a water filter. The sewage has a tendency to spread evenly over the surface of the plot, filtration apparently commencing when the head of water on the soil is sufficiently deep to overcome the resistance of the sludge. From this it would appear that the whole of the plot does its work more equably than when this coating of sludge is absent.

CAMBRIDGE SEWAGE FARM.



Weller & Graham Ltd Litho London.

CAMBRIDGE SEWAGE FARM.

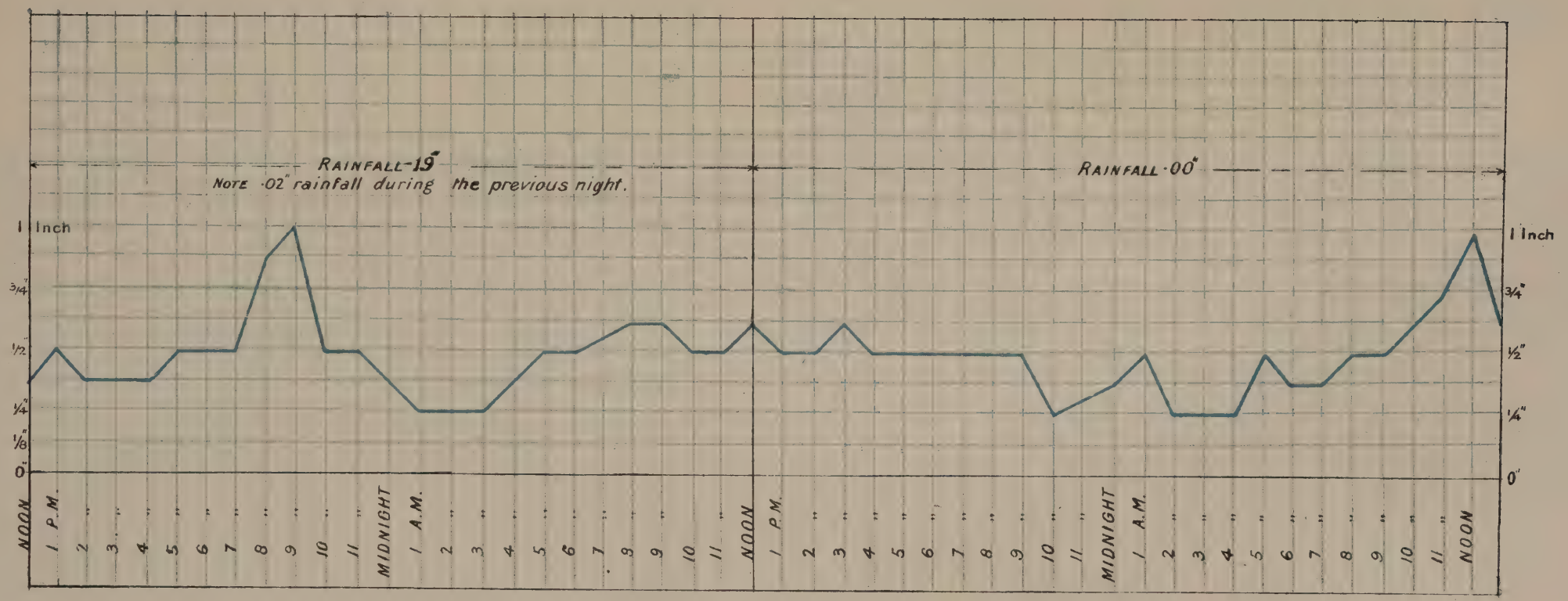


SECTION OF SOIL AND SUBSOIL.

3311 8 02.
Weller & Graham Ltd Litho. London.

CAMBRIDGE SEWAGE FARM

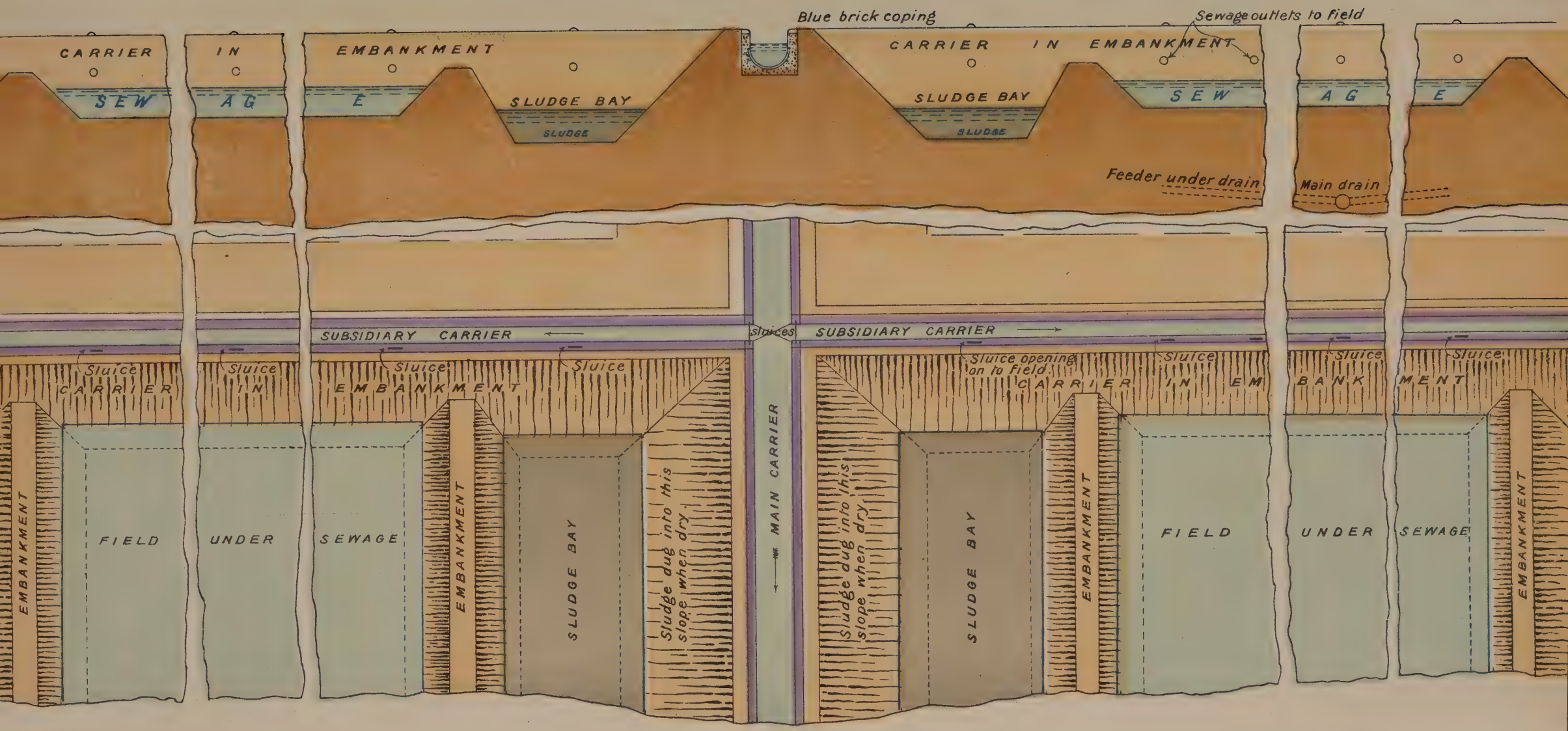
Diagram shewing depths of sewage passing over Settling Tank cill during 48 hours:-



Weller & Graham: Ltd Litho. London.

Addendum B.
III.

DIAGRAMMATIC PLAN & SECTION, SHEWING FIELDS UNDER SEWAGE.



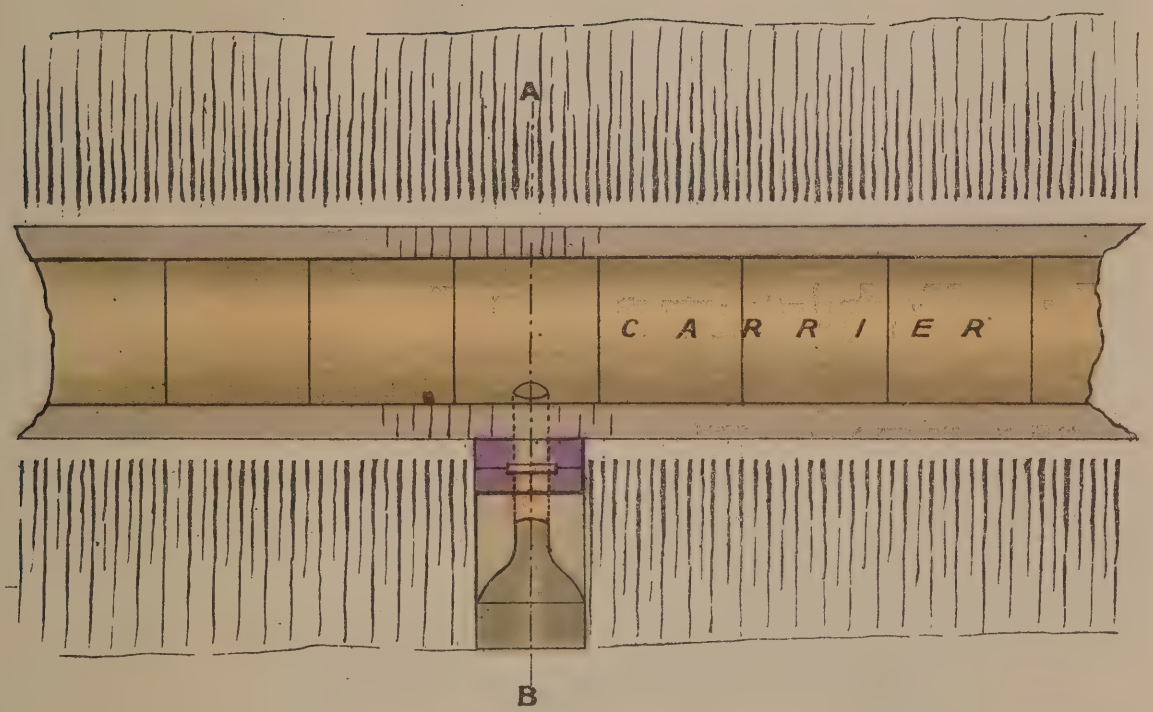
3311 8 02

Weller & Graham, Ltd Litho. London.

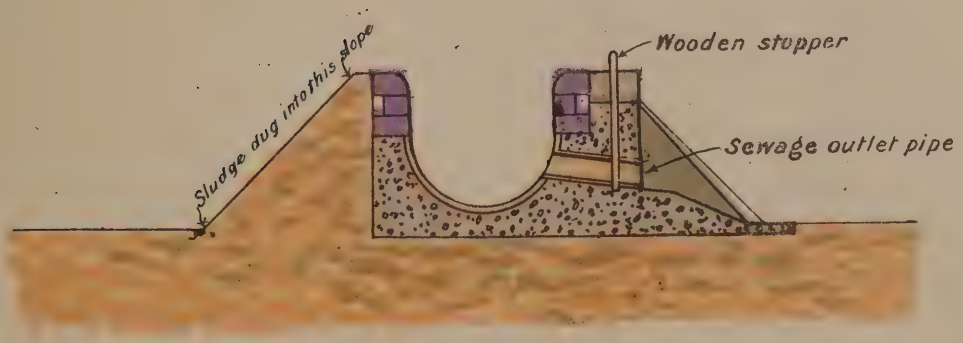
IV.

CAMBRIDGE SEWAGE FARM.

DETAIL OF
CARRIER SEWAGE OUTLETS.



PLAN.



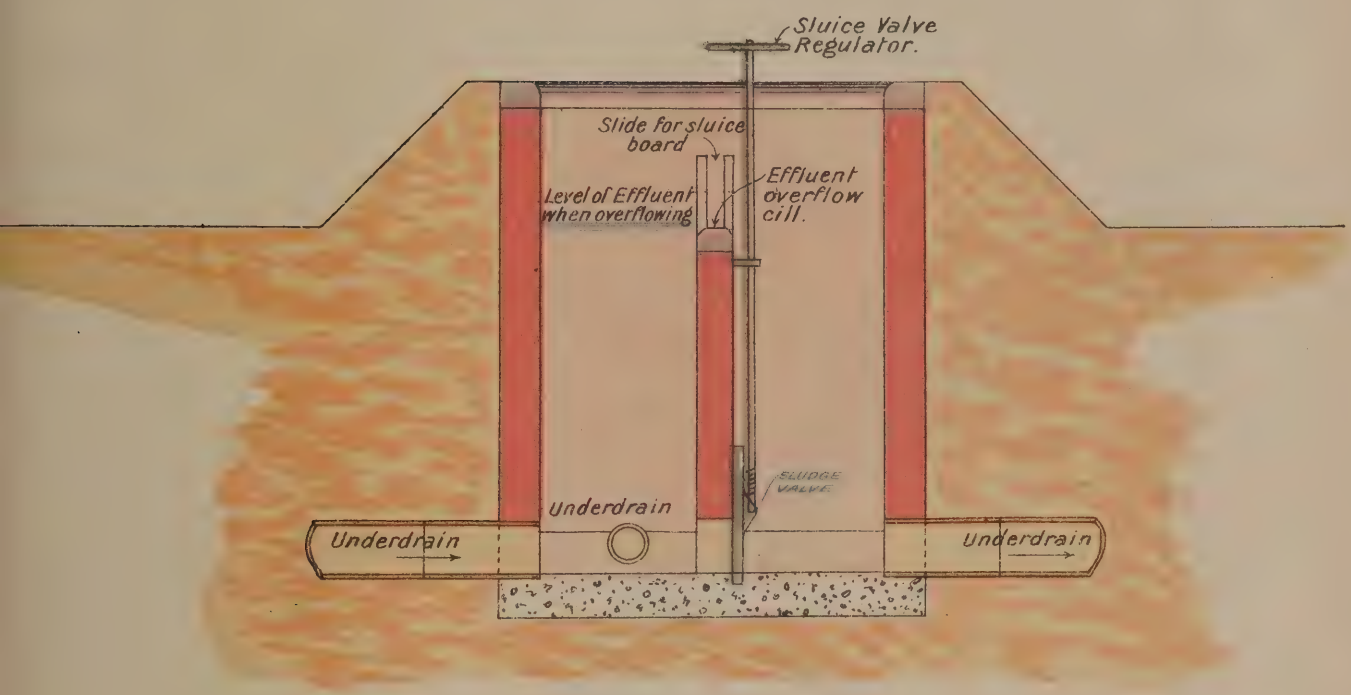
SECTION A.B.

3311. 8. 02

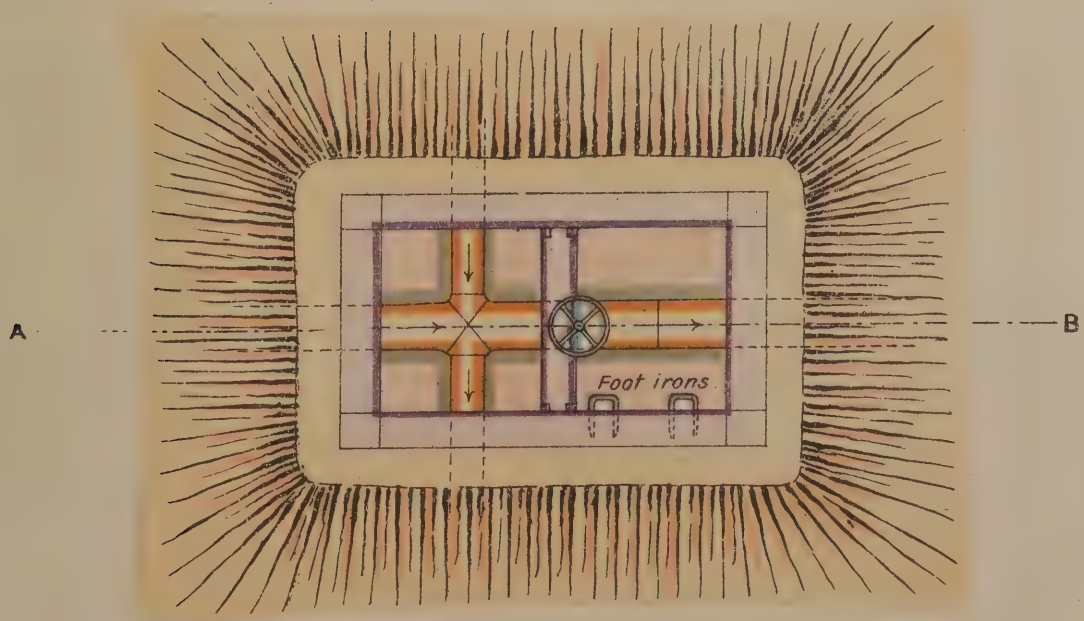
Weller & Graham Ltd Litho. London.

CAMBRIDGE SEWAGE FARM.

MANHOLE FOR HOLDING UP THE SEWAGE IN CONTACT WITH THE SOIL.



SECTION A.B.



PLAN.

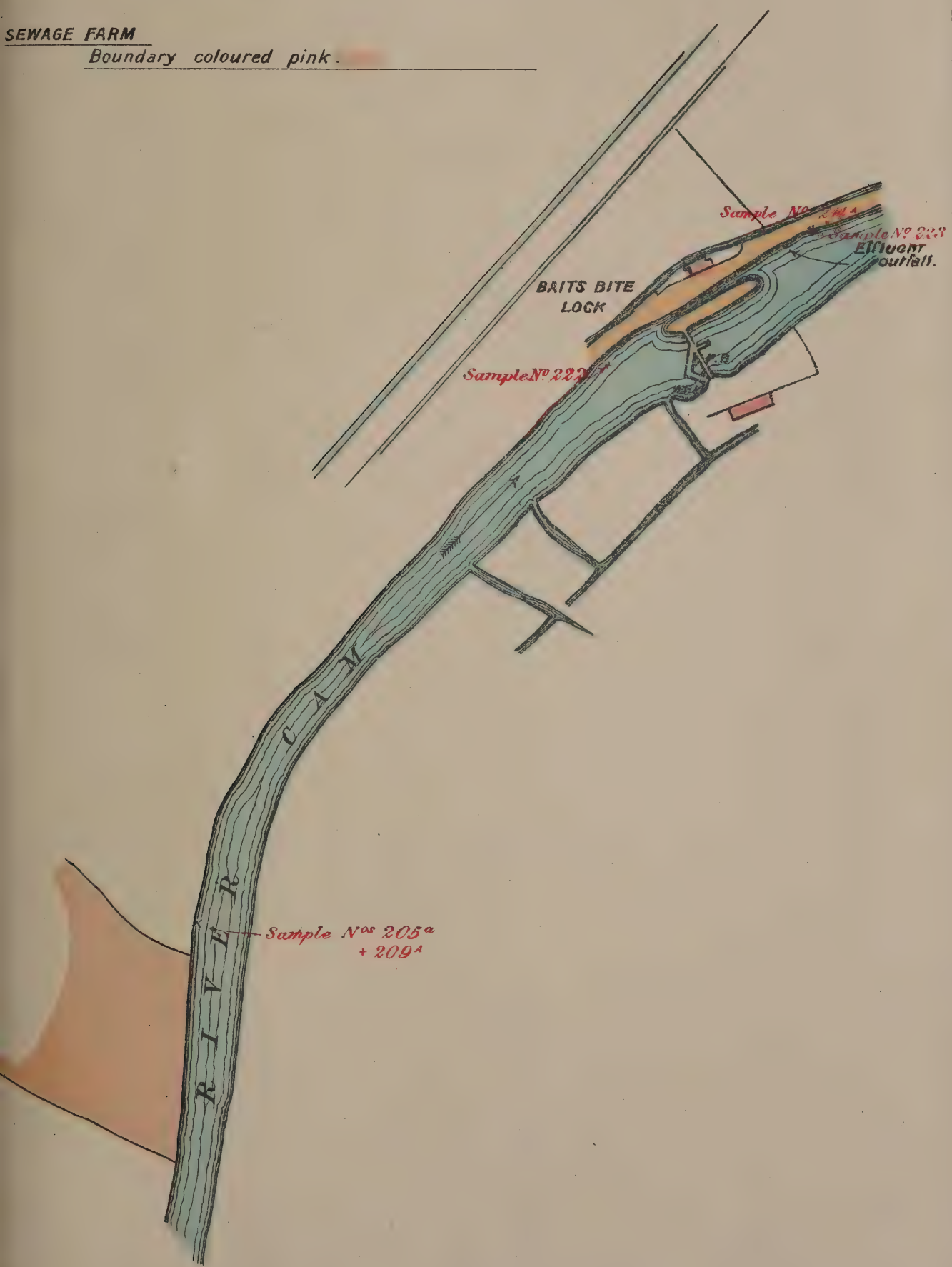
Weller & Graham Ltd Litho London.

CAMBRIDGE SEWAGE FARM.

(RIVER SAMPLES.)

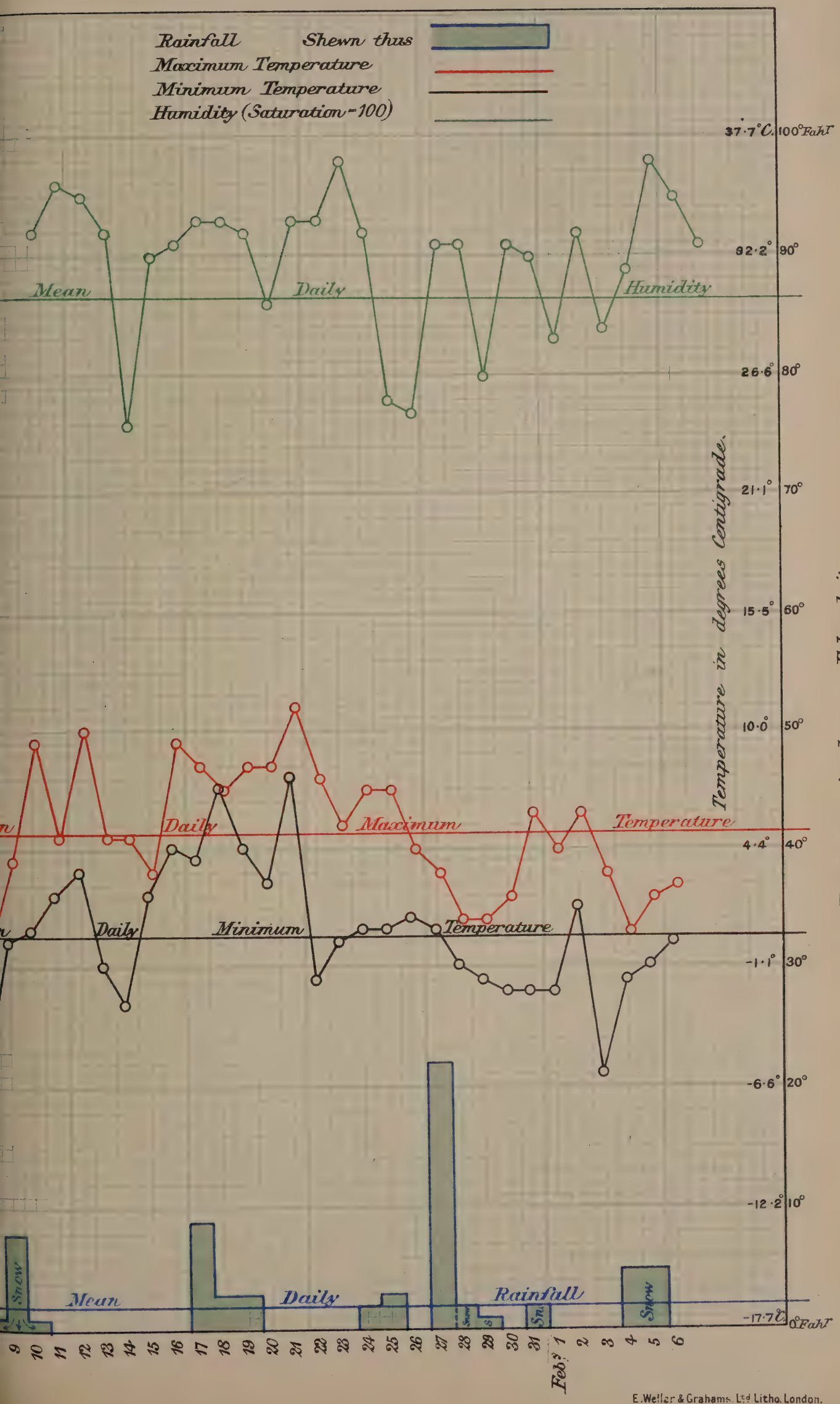
Scale:-25·344 Inches to One Mile.

SEWAGE FARM
Boundary coloured pink.



Weller & Graham Ltd Litho. London.

CAMBRIDGE SEWAGE FARM.



E. Weller & Grahams. Ltd Litho. London.

LEICESTER (Beaumont Leys) SEWAGE FARM.

(LEICESTER CORPORATION).

1. Situation of farm—Beaumont Leys, about two miles from Leicester.
2. Total acreage of farm—1,699 acres.
3. Total irrigable area—1,350 acres.
4. Average area irrigated at one time—337 acres.
5. Population draining to farm—197,000.
6. Population per acre irrigated—146.
7. Gallons of sewage per head per day—36·8.
8. Dry weather flow of sewage per 24 hours—7,250,000 gallons.
9. Gallons of sewage (exclusive of storm-water) treated per acre per 24 hours—21,500 gallons = $(\frac{7250000}{337})$.
10. Gallons of sewage treated per acre per 24 hours, on the assumption that each acre of irrigable area is under sewage all the time. (This for purposes of comparison)—$(\frac{7250000}{1350})$ = 5,370 gallons.
11. Characters of the sewage—Domestic about three-fourths, trade refuse nearly one-quarter.
12. Method of treatment — Screening, settling tanks, surface irrigation, and filtration combined.
13. General characters of the soil and sub-soil—Stiff clayey soil overlying dense clay.
14. Separate or combined sewerage system—Partially separate.
15. The final effluent is discharged into—Anstey Brook flowing into river Soar.
16. Number of years farm in operation before 1900 :—9 years.

LEICESTER (Beaumont Leys) SEWAGE FARM REPORT.

SUMMARY OF CONTENTS.

DESCRIPTION OF FARM.

Addendum A.—Notes on Samples.

Additional Notes on Samples.

Table I.—Shewing all samples drawn at the Leicester (Beaumont Leys) Sewage Farm together with time of drawing, rainfall, temperatures, description of samples, etc.

Table II.—Giving area of plots from which effluents were drawn, and the time those plots had been under sewage, etc.

Table III.—Comparative samples.

Addendum B.—Plans and Diagrams referred to in report.

I.—Plan of farm.

II.—Plan referring to brook water samples, and section of soil and subsoil.

III.—Pumping diagrams.

IV.—Diagram showing hourly depths of sewage passing over tank cills.

V.—Temperature and rainfall chart—(first visit).

VI.—Temperature and rainfall chart—(second visit).

VII.—Temperature and rainfall chart—(Experiment).

VIII.—Diagram shewing number of gallons treated per acre during the experiment.

LEICESTER (Beaumont Leys) SEWAGE FARM.

(Leicester Corporation.)

(Domestic Sewage and Trade Refuse.)

The soil of this farm is clay. The surface soil over the greater portion is of a stiff, clayey nature 6in. to 12in. deep over 2ft. 6in. to 3ft. of yellow clay overlying hard boulder clay and the keuper marl. (Add. B. II.) About 25 to 30 acres of the farm in the vicinity of the Anstey Brook are of rather a better nature, having a certain depth of alluvial soil.

The sewage, which contains a large amount of trade refuse, is treated by means of screening, settling tanks, surface irrigation and filtration combined. The farm is managed by the Leicester Corporation.

Some of the land has been somewhat lightened by ploughing in the sludge.

There is practically no subsoil water on the farm.

No cinders have at any time been ploughed in. Sewage has been treated on the farm for about nine years (viz., from September, 1890).

The dry weather volume of the domestic sewage and trade refuse combined amounts to (1899) about 7¼ million gallons per 24 hours, or about 37 gallons per head. This volume is made up as follows :—

	Gallons.
Domestic Sewage - - -	3,750,000
Trade Refuse - - - -	2,000,000
Well and Subsoil Water - -	1,500,000
Total - - -	7,250,000

The trade water comes from eleven dye works, ten wool scourers' and spinners' works, two fellmongers, and one currier, and constitutes a little less than one-fourth of the total sewage flow.

The dense trade liquor, Mr. Mawbey, the Borough Engineer, estimates at half a million gallons.

The sewage contains a large amount of fibre, apparently resulting from the wool scouring.

Manufacturers are required to arrest solids only by settlement in small catch pits with gratings before letting the waste liquor into the sewers. When the catch pits have not been cleaned out for some time, the solids wash out into the sewers.

Plans have to be submitted for all new work in connection with these catch pits. The refuse is turned into the sewers at any time convenient to the manufacturer, and not equably.

The area of the borough (1899) is 8.586 acres, with a rateable value of £783,386.

The total population of the borough is (1899) 215,000 ; of this total * 197,000 drain to the Beaumont Leys Farm, and the remainder to two other smaller farms.

The drainage area (built area) of the town draining to the farm is about 1,970 acres, or one acre to every hundred persons.

The public water supply is about 19 gallons per head, obtained from various gathering grounds in Leicestershire.

The town is chiefly on the w.c. system, 37,000 w.c.'s being connected to the sewerage system. Privies and slop closets number about 4,838, of which

---

* 10,000 persons on the pail closet system are included in this total of 197,000. This system is being replaced by w.c.'s.

number 4,700 are pail closets. As at Nottingham, the house slop water drains to the sewers. The night soil is collected and sent in vans to the country and sold.

The system of sewerage in use at Leicester is chiefly the combined system For some years past the separate system has been carried out in all new streets, but the storm and surface water sewers have in many cases to be temporarily connected to the foul water sewers, until the completion of the separate system, thereby neutralising to a great extent the benefit of the separation.

A large proportion of the Leicester streets are macadamised, and the road detritus therefrom causes a large amount of sludge.

In time of rainfall, and particularly after a fall of snow, this road grit is washed into the street gullies, and a large proportion of it finds its way into the sewers, some being carried at once to the settling tanks at the sewage farm, and some remaining in the sewers until the next storm washes it out, or until it is removed by the sewer cleansing machines.

The average rainfall per annum at Leicester for the past six years is shown in the table below.

	Inches.	
1893 - -	16·18	Gaugings taken with a 5in. gauge.
1894 - -	18·84	
1895 - -	21·13	
1896 - -	21·89	
1897 - -	21·86	
1898 - -	19·73	
	119·63	

Average for six years = 19·94in., or about 20in. per annum.

The present sewerage system is in good condition, and there is very little subsoil leakage; main intercepting sewers of recent date were completed in 1892.

The brick sewers are flushed by an automatic cleansing machine driven through the sewers, the motive power being provided by the head of sewage backed up behind the machine.

Pipe sewers are cleansed by flushing manholes, provided with quick-lifting penstocks.

The main gravitation outfall sewers to the storm overflow chamber, consist of two 6ft. 9in. by 4ft. 6in. sewers; and from the overflow chamber to the pumping station one 5ft. diameter cast-iron circular pipe is employed.

The gradient of this 5ft. outfall sewer is 1 in 600, and its capacity running full 5,458 C.F.M.

The whole of the sewage gravitates to the pumping station, the average time the dry weather sewage takes to reach the above point from the centre of the borough being about $1\frac{1}{4}$ hours.

The main storm overflow weir is placed in a large storm overflow chamber, near the pumping station, a culvert 8ft. in diameter and $3\frac{3}{4}$ miles long conveying the storm water to the River Soar, near Wanlip.

There are, in addition to the above, seven local storm overflows situated in various parts of the borough, and discharging into the canal and the River Soar.

The main storm overflow comes into action when the combined volume of sewage and storm water passing to the pumps exceeds twice the dry weather flow; that is to say, that twice the dry weather flow is lifted by the pumps to the farm and there treated, and the remainder passes off by the main storm culvert.

This culvert comes into operation, on the average, sixty times during the year. The Corporation are required by Act to pump up to 60 gallons per head per day to the farm, but pump more.

The local overflows work when the rainfall exceeds the rate of 2in. per 24 hours, or $\frac{1}{2}$in. in $1\frac{1}{2}$ hours.

The sewage on arrival at the pumping station passes through two

movable iron gratings or screens with $\frac{3}{4}$in. spaces, to arrest matters likely to injure or clog the pumps, the screenings being carted away and sold. After passing these screens the sewage flows at once to the pump well, and is lifted to the farm by four engines. (Add. B. III.)

The quantity each engine will lift is about 200,000 gallons per hour, or 800,000 gallons when all four engines are used together.

The rising mains from the pumping station to the farm consist of two 33in. diameter cast-iron pipes, terminating in bell-mouthed outlets, 3ft. 9in. in diameter, discharging into the settling tanks on the farm $1\frac{1}{2}$ miles distant.

The height the sewage is lifted is 169·5ft., and the time the sewage takes to reach the tanks from the pumping station about one hour.

The settling tanks are placed on the highest point (about the centre) of the farm, and are very small in proportion to the volume of sewage treated. They are three in number, and are all used simultaneously, except during cleaning operations. The size of the settling tanks is, each, 98ft. 6in. long by about 6ft. deep (average depth), one tank being 63ft. wide and two 63ft. $10\frac{3}{4}$in. wide, built of Staffordshire blue bricks in cement. Scumboards 18in. deep and $1\frac{1}{2}$in. thick are fixed at the foot of each tank.

Each tank has a capacity of 200,000 gallons (or one hour's pumping of one engine), giving a total combined capacity of 600,000 gallons (*i.e.*, less than 10 per cent. of the normal dry weather flow). (Add B. IV.) They are worked on the continuous system, no chemicals whatever being used, and are cleaned out once in three weeks by means of a steam-driven chain pump. The tank effluent is drawn off by valves placed in the corner of each tank, the sludge gravitating to, and being lifted from, the sludge slump into the carriers and emptied on the sludge areas, or sludge lagoons if empty. Some of the sludge from the lagoons is sold to farmers, and some is ploughed into the land. Owing to the great length of time the sludge takes to dry sufficiently for carting away, the sludge in the lagoons is apt to create a nuisance, especially in hot weather; the isolated position, however, of the tanks and sludge lagoons renders this less objectionable than would otherwise be the case, except in their immediate vicinity. The tanks remove as sludge about one-half of the suspended solids in the sewage. A thick fibrous scum of from 3in. to 15in. thick forms on the surface of the tanks, particularly in hot weather and in the absence of wind.

The sewage is taken from the settling tanks along main carriers constructed of blue brick in cement, and provided with sluices at intervals for turning the sewage on to the land, or into the subsidiary carriers. Pipe carriers are also employed for distributing the sewage, and contoured grips on the pasture land. Where a sudden change of level takes place in the carriers, ramps are provided.

The cost of preparing the land up to the present date (1899) has been £58,900, inclusive of all constructional works on the farm and road-making.

The total cost of sewage disposal works, including farm, rising mains, and pumping station, was £279,676.

The method of irrigation is to send the settled sewage over one arable field, and then over one or more pasture fields. Whilst the tanks are being cleaned out (this is usually done on a Monday, as the trade refuse is less on that day), the crude sewage goes on to the land, and where the grass plots sewaged lie at some distance from the tanks, the settled sewage is sometimes run on to the pasture land direct (*i.e.*, not having previously passed over an arable field), a good deal of sedimentation having taken place in the carriers, and the grass is, therefore not damaged. After ploughing, some of the land is steam cultivated about 12in. to 15 in. deep, and takes much more sewage subsequently. The steam ploughing removes the effects produced on the land by the horses' feet, and lightens the soil considerably.

The total acreage of the farm is 1,699 acres. The total area actually irrigated is about 1,350 acres, of which area about 902 acres are pasture and 448 arable.

This area has all been irrigated at one time or another; but one or two fields are now kept to turn horses and bullocks into, and are not irrigated.

About 350 acres are utilised for grazing purposes at times when the cattle cannot all be upon the sewaged land.

This area of 1,350 acres deals with $7\frac{1}{4}$ million gallons per 24 hours (exclusive of storm water). The population being 197,000, this gives 146 persons per acre of irrigable area, or 5,370 gallons per acre (at 36·8 gallons of sewage per head, inclusive of trade refuse).

Approximately, one quarter of the irrigable area is under sewage at one time, and this gives about 21,000 gallons of sewage treated per acre per 24 hours.

The average number of gallons of settled sewage treated per acre per 24 hours on the arable land is about 64,000, and subsequently on the pasture land about 32,000, that is to say, that the pasture land employed at one sewaging is approximately double the area of the arable land so used.

The land was prepared for receiving sewage in the following manner :— The old ditches were deepened and cleaned out to form main effluent drains to the streams, and the underdrains of each field have separate outfalls brought out on the surface of the next lowest field, and so arranged that a bad effluent reaching the drains through the clay can be re-treated a second or third time on other areas as may be required.

This is left to the discretion of the watermen, but as a rule an effluent is not sent off the farm until it has been treated at least twice.

The underdrains are ordinary agricultural butt tiles and are laid from 24ft. to 99ft. apart, averaging 4ft. in depth. Where additional underdrains are now required they are put in at a depth of 3ft. Two fields are drained 8ft. deep.

The diameter of the underdrain varies ; 4in. to 6in. master drains are employed.

Formerly, the drains, when made, were filled in with top soil only ; they are now filled in with the same soil as that excavated.

The general system of underdrainage may be spoken of as being effected by means of 4in. butt land tiles connected to a 6in. master drain laid along the lowest sides of the field. At the lowest corner of the field this 6in. master drain is provided with a valve chamber and outfall on to the next field below, so that the drain effluent can, if necessary be re-treated on the surface, or turned into the ditches, if adequately purified. If the plots under irrigation are large and long, only two might be used, if, *per contra*, small, then three or even four plots might be employed (*i.e.*, double, treble, or quadruple land treatment is used). Surface effluents are carried across the ditches where necessary by means of a trough.*

The contour of the farm lends itself to this mode of treatment. The land being drained, horses can be got to work much sooner after sewaging than would otherwise be the case.

The land cracks badly in hot weather.

In the case of the Beaumont Leys sewage farm, the system of underdrains described above answers well, owing to the facility with which the effluents can be picked up and re-treated, this being assisted by the conformation of the land.

In a flat clay district, however, this would be impracticable without pumping ; and consequently there would be the danger that the effluent would escape to the brook or river, imperfectly treated.

About 330 to 350 acres are irrigated at one time, this area being generally made up of about one-third arable and two-thirds pasture.

The sewage as a rule goes on the same plots continuously day and night for about 14 days ; this to some extent tends to stop the cracks in dry weather, but on the other hand it sometimes has a tendency to overdo the land, and possibly good results might be obtained by sewaging, say for 7 days continuously, and after that only employing night sewage (12 hours) for the remaining period of 7 days.

About 1,111 acres of land are cropped at Beaumont Leys. Of this area 910 acres are irrigable, and consist of roots, wheat and oats ; 20 to 30 acres

---

* As in the case of Rugby the proportion of surface and filtration effluent varies greatly. Under ordinary circumstances the surface and filtration effluents are approximately equal when a field has been sewaged, say, for 3 or 4 days and there has been no rain. After this, the surface effluent usually preponderates, cracks in the ground silting up by degrees On the other hand, when a field has not been sewaged for some time in dry weather, the whole of the effluent is from the underdrains, until the sewage reaches the bottom of the field.

of wheat are usually grown for thatching purposes; 600 acres of hay were cut in 1899.

Mangold wurzels are also grown, but rye grass constitutes the principal crop.

Nearly all the mangolds are consumed on the premises; the rye-grass is used on the farm and supplied to the town (Corporation) horses. With the exception of mangolds (which are occasionally sewaged in hot weather to start them), permanent pasture and rye-grass, the crops are very rarely irrigated when growing.

A large herd of bullocks is kept on the farm, frequently as many as 1,000 at a time, and these do considerable damage to the irrigation land, treading in the heavy soil, and forming pockets for the sewage to stagnate in, when the area is being dried off. They have access to the effluent on the old pasture, which, however, is usually after the second application. The operations attending the removal of the sludge from the settling tanks take some time, and are attended by considerable smell, and this nuisance is accentuated in hot weather; the smell, however, does not reach a great distance from the tanks, except in damp, foggy weather. About 86 men are required to work the farm in winter and about 130 in summer.

There is a loss of several thousand pounds annually on the year's working, the loss for the year ending March 31st, 1899, being £7,748 (exclusive of interest on loan).

The cost per 1,000,000 gallons of sewage treated is:—

For pumping - - - - - -	£1·602	
For treating on farm - - - - -	£2·860	
	£4·462	(exclusive of interest on loan.)

Twenty men are constantly employed in looking after the distribution of the sewage, in addition to the head waterman.

The chief difficulty experienced in working the farm is the disposal of the sludge, on account of the long time it takes to dry sufficiently to admit of removal, and the large area of land which has to remain uncropped in consequence of the necessity for reserving a place for the deposit of some of this sludge.

There are six effluent outfalls from the farm, five of which discharge into the Anstey Brook—which joins the River Soar later on—and one to the River Soar direct.

In summer the volume of the Anstey Brook is sometimes less than the combined volumes of the several effluents from the farm.

The Anstey Brook at the time of the visits to the farm—(November, 1899, August and September, 1900, and October, 1901)—appeared to be in a clean state; the stream has a fairly rapid current in places, with a gravelly bottom and an abundance of weeds and green growths. Holes occur in places from 3ft. to 6ft. deep and some of these contain fish. The brook contained a fair amount of dissolved oxygen. The effluent from another small farm close by runs into the brook below the Leicester outfall. There was no smell or sewage fungus noticeable.

Notes on Temperature, Rainfall, etc.

The mean daily rainfall during the November visit was ·46 inch. The only rainfall of any note occurred on the 7th and 10th November, 1899. The mean daily maximum temperature taken at 9 a.m. was 10·7° C. (51·3° Fahr.), the mean daily minimum 3·6° C. (38·6° Fahr.), and the mean daily temperature of the settled sewage coming from the tanks at 12 o'clock (noon) 13·8° C. (57° Fahr.).

In the summer visit (August and September, 1900), the mean daily rainfall was ·048 inch during 22 days, the mean maximum and minimum for the period being 20·4° C. (68·86° Fahr.), and 8·5° C. (47·31° Fahr.) respectively. During the experiment the mean daily rainfall was very low, being only ·009 inch, maximum temperature 21·1° C. (70·17° Fahr.), and minimum temperature 7·3° C. (45·29° Fahr.).

The only rainfall of any consequence during the above two periods was on August 23rd when ·63 inch occurred during the 24 hours. (See Add. B. V., VI., and VII.).

ADDENDUM A.

LEICESTER SEWAGE FARM.

(Domestic Sewage and Trade Refuse.)

Additional Notes.

Sample 1.—Taken after heavy rain, and rather dilute.

Sample 2.—Surface effluent means one which has travelled over the surface of the land and has not reached the underdrains :—After the sewage had passed over the first field, all samples were almost invariably surface and filtration effluents, as these effluents are collected in a manhole at the lowest point of the first field and sent on to the next field mixed together. (No. 2 sample contained some suspended matter and was slightly turbid.)

Sample 3.—Taken during a sharp shower which apparently affected the effluent as regards suspended matter and turbidity.

Sample 4.—General effluent. The sewage from which this effluent was derived was very soapy.

Sample 5.—Subsoil water taken from a high portion of the farm which had never been actually sewaged within 50 yards. (The sample was from a small sandy stratum in the Boulder Clay.)

Sample 6.—Water rather turbid at time of drawing. (Taken 80 yards below effluent outfalls.)

Sample 7.—Screened and settled sewage ; normal.

Sample 124.—Screened and settled sewage. (The tanks had been cleaned out the day previous to drawing samples, and the settled sewage appeared to contain less suspended matter.)

Sample 126.—The grass land this effluent came off was in very good condition.

Sample 127B .—Brook very low ; water clear.

Sample 128.—Sewage rather strong.

Sample 130A.—Brook low.

Sample 131.—Final effluent turbid ; some fragments of straw. (Bullocks in field probably stirred up some sediment.)

Sample 132.—General effluent taken from two general effluent outfalls, both flowing at about the same rate. (Half a sample bottle taken from each outlet.)

Sample 133.—Brook about normal and very fairly clear. (Taken 16 yards above effluent outfall.) (Add B. II.).

*Sample 134.—A fairly clear sample. (Taken 20 yards below effluent outfalls.)

*Sample 135.—A fairly clear sample. (Taken 180 yards below effluent outfalls.)

EXPERIMENTS.

The following samples were taken with a view to ascertaining by daily increased doses of sewage the limit of the purifying power of the soil. The daily increment being about 3,000 gallons.

Sample 136.—When this sample was drawn the tanks were being cleaned out and only one was in use instead of three. The sample did not appear to be particularly strong.

Sample 137.—Final effluent, fairly clear. The sewage was run over an arable field first (6·5 acres) and then on to a pasture field (10·5 acres) total 17·0 acres. The arable field was stubble and there was very little grass on the pasture field, the bullocks only having been taken off that day. The dose of sewage was started at about 200,000 gallons for the 17 acres per 24 hours on September 10th 1900 at noon.

Sample 137.—Owing to the small amount of sewage being applied only about 2 acres of the arable and 4·5 acres of the pasture were covered by the sewage ; the effluent then reaching the drains through cracks in the soil, and could only be obtained after mixing with an effluent from another field.

Sample 138.—This sample was drawn before having mixed with the other effluent. About 2·5 acres arable and 4·5 acres pasture were now covered by the sewage.

The effluent did not appear to be good. About 265,000 gallons of sewage were being sent on to the area. † Owing to the dryness of the soil, it was thought advisable to soak the land thoroughly, that being the method usually employed in irrigating the land, and on September 13th (noon), 900,000 gallons of sewage per 24 hours were put on the land for three days, 3·5 acres arable and 4·75 pasture being covered on September 14th, and the grass appeared to have benefited considerably where irrigated.

On September 15th, 4·75 acres arable and 4·75 acres pasture were being irrigated, and a large

---

* Note with regard to the above samples, it appeared likely from the nature of the soil adjoining the brook that percolation of effluent from the farm might under certain circumstances find its way into the brook at various points.

† When small quantities of sewage are run on to land, the sewage nearly always has a tendency to follow certain defined channels, but when the entire surface has been thoroughly wetted, the sewage flows over the surface far more evenly.

quantity of surface effluent was flowing from the grass land, which had greatly improved in appearance. The effluent too appeared better.

On September 16th the whole 6·5 acres of arable and 5 acres pasture were being irrigated, and some surface effluent was flowing off the arable. The flow of sewage at noon was cut down from 900,000 gallons to 200,000 for the entire area.

Sample 139. September 17th.—There was not much effluent coming off the pasture land; and it did not appear to be very good. The flow was increased to 250,000 gallons at noon.

Sample 140. September 18th.—There was still very little effluent coming off the pasture. A clearer sample than No. 139. Sewage flow increased to 300,000 gallons at noon.

Sample 141. September 19th.—This sample was not so yellow in colour as the previous ones, and had very little smell. A good crop of grass on the irrigated portion. Sewage flow increased to 350,000 gallons at noon.

Sample 142. September 20th.—A clearer sample than previously. Sewage flow increased to 400,000 gallons at noon.

Sample 143. September 21st.—This sample did not look so good as the preceding one. This may perhaps be accounted for by the fact that the arable land effluent was removed to another portion of the pasture land, in order to give the part previously sewaged a rest as it was becoming over sewaged. This would be equivalent to starting a new field. There was an exceedingly poor crop of grass on the non-irrigated portions of the field. Sewage flow increased to 450,000 gallons at noon.

Sample 144. September 22nd.—This sample of effluent seemed very bad, probably owing to a new piece of pasture land being irrigated. Flow increased to 500,000 gallons at noon.

Sample 144A. September 23rd.—The effluent appeared clearer than the day previous. Flow increased to 550,000 gallons at noon.

Sample 145. September 24th.—The effluent seemed improving, very slight smell. Grass commencing to grow well. Flow increased to 600,000 gallons at noon.

Sample 146. September 25th.—Effluent had a slight smell. The grass appeared to be deteriorating, the amount going on appearing to be about the limit the grass land can take without injury. Flow increased to 650,000 gallons at noon.

Sample 147. September 26th.—The effluent appeared better. A vast quantity of small white worms in the sewage, and also in the effluent. Those in the sewage varied in length from $\frac{1}{4}$ inch to $\frac{1}{2}$ inch and those in the effluent were about $\frac{1}{64}$th in. long. Flow increased to 700,000 gallons at noon.

Sample 148. September 27th.—Not much change in the effluent apparently, the grass not looking so well, and much sediment round the roots. *Note.*—A diagram is appended shewing the actual amounts of sewage treated per acre.—(Add. B, viii).

End of experiment.

Sample 350.—First field effluent, turbid and strong sewage smell. Owing to the tanks being cleaned out, some sewage was being pumped directly on to this field, stirring up the silt.

Sample 354.—General effluent, very yellow colour. This is especially noticeable when bullocks have been upon the irrigated area, and the grass bruised and trampled upon.

Sample 356.—General effluent, very frothy on being shaken.

Sample 358.—First field effluent, a lot of suspended matter coming off the arable field.

Sample 362.—First field effluent, black and septic looking.

Sample 365.—Settled sewage, after heavy rain, not much sediment.

Sample 366.—Some flocculent suspended matter.

LEICESTER SEWAGE FARM.

TABLE I.

(Domestic Sewage and Trade Refuse.)

Number of Sample.	Date of Drawing Sample.	Time of Day	Rainfall Day previous to drawing Sample.	Rainfall Day of drawing Sample.	Air Temperature time of drawing Sample.	Temperature of Sample.	Maximum Temperature during the 24 hours.	Minimum Temperature during the 24 hours.	Humidity (9 a.m.)	Dissolved Oxygen in Sample.	Brief Description of Sample.	Remarks.
	1899.		Inches.	Inches.	°C. °F.	°C. °F.	°C. °F.	°C. °F.				
1	8 November -	11.15 a.m.	·07	·24	11·1 (52)	12·7 (55)					Screened and settled sewage.	
2	8 ,, -	12.30 p.m.	·07	·24	11·1 (52)	11·1 (52)					First field effluent.	Mean daily max. temp. 10·7 °C. (51·3) °F. Mean daily min. temp. 3·6 °C. (38·6) °F.
3	8 ,, -	3.00 p.m.	·07	·24	10· (50)	9·4 (49)					Final effluent.	Mean daily rainfall ·046 in.
4	14 ,, -	3.00 p.m.	·00	·00	10· (50)	9·4 (49)					§General effluent.	For the period Nov. 8th to Nov. 21st, 1899.
5	15 ,, -	1.15 p.m.	·00	·00	9·4 (49)	10·5 (51)					Subsoil water.	Samples which may have been affected by rainfall are underlined.
6	20 ,, -	2.30 p.m.	·00	·04	9·4 (49)	9·4 (49)					Brook water and effluent	
7	21 ,, -	12 (noon)	·04	·01	7·2 (45)	14·4 (58)					Screened and settled sewage.	§ By "general" effluent is meant a mixture of two or more finally treated effluents on leaving the farm.
8	21 ,, -	1.30 p.m.	·04	·01	7·2 (45)	7·2 (45)					First field effluent	
9	21 ,, -	2.45 p.m.	·04	·01	6·6 (44)	6·6 (44)					Final effluent	
	1900.									c.cs.		
124	21 August -	12.30 p.m.	·00	·15	20·5 (69)	17·7 (64)	21·6 (71)	10·5 (51)		2.	Screened and settled sewage.	
125	21 ,, -	1.30 p.m.	·00	·15	22·2 (72)	21·1 (70)	21·6 (71)	10·5 (51)		2·	First field effluent	
126	21 ,, -	3.15 p.m.	·00	·15	21·6 (71)	20· (68)	21·6 (71)	10·5 (51)		5·	Final effluent	Mean daily max. temp. 20·4 °C (68·86) °F. Mean daily min. temp. 8·5 °C (47·31) °F. Mean daily rainfall ·048 in.
127A	22 ,, -	12 (noon)	·15	·00	18·8 (66)	21·6 (71)	21·1 (70)	12·7 (55)		3·50	Intermediate effluent	
127B	22 ,, -	1.00 p.m.	·15	·00	16·1 (61)	17·7 (64)	21·1 (70)	12·7 (55)		6·50	Brook water	
127	22 ,, -	2.00 p.m.	·15	·00	16·6 (62)	18·8 (66)	21·1 (70)	12·7 (55)		5·50	Final effluent	For the period August 20th to September 10th, 1900.
128A	27 ,, -	12.15 p.m.	·02	·00	17·7 (64)	17·2 (63)	17·7 (64)	11·6 (53)		2·75	Intermediate effluent	
128	27 ,, -	11.15 a.m.	·02	·00	15·5 (60)	15·5 (60)	17·7 (64)	11·6 (53)			Screened and settled sewage.	
129	27 ,, -	2.00 p.m.	·02	·00	16·1 (61)	16·6 (62)	17·7 (64)	11·6 (53)		3·	Final effluent	
130A	29 ,, -	12 (noon)	00	00	16·6 (62)	14·4 (58)	21·6 (71)	9·4 (49)		5·50	Brook water	
130	29 ,, -	11.45 a.m.	·00	·00	16·1 (61)	14·4 (58)	21·6 (71)	9·4 (49)		2·	General effluent	
131	30 ,, -	11.30 a.m.	·00	·00	18·8 (66)	17·7 (64)	25· (77)	6·6 (44)		·50	Final effluent	

132	3 September	11.45 a.m.	·00	·00	17·2 (63)	15· (59)	17·7 (64)	5·5 (42)	6·50	Brook water above effluent outfalls.	
133	3 September	12. (noon)	·00	·00	17·2 (63)	13·3 (56)	17·7 (64)	5·5 (42)	6·	Brook water and effluent	
134	3 ,,	12.30 p.m.	·00	·00	16·6 (62)	13·8 (57)	17·7 (64)	5·5 (42)	5·	Brook water and effluent	
135	3 ,,	1.00 p.m.	·00	·00	17·7 (64)	14·4 (58)	17·7 (64)	5·5 (42)			
						EXPERIMENT.					
136	10 ,,	12. (noon)	·00	·00	18·3 (65)	17·2 (63)	18·8 (66)	5·5 (42)	—	Screened and settled sewage.	
137	11 ,,	1.00 p.m.	·00	·00	15·0 (59)	15·5 (60)	23 3 (74)	6·1 (43)	3·75	Final effluent.	Mean daily max. temp. 21·2° C. (70·17) °F.
138	12 ,,	12. (noon)	·00	·00	22·7 (73)	17·2 (63)	20·5 (69)	5·0 (41)	3·	Final effluent.	Mean dailymin. temp. 7·2° C. (45·29) °F.
139	17 ,,	12. (noon)	·02	00	18·3 (65)	16·6 (62)	22·7 (73)	8·3 (47)	1 25	Final effluent.	Mean daily rainfall ·009 in.
140	18 ,,	12. (noon)	·00	.02	17·2 (63)	16·6 (62)	21·6 (71)	1·1 (34)	1·50	Final effluent.	For the period September 11th to September 27th, 1900.
141	19 ,,	12. (noon)	·02	·00	20·5 (69)	20·5 (69)	19·4 (67)	2·7 (37)	1·75	Final effluent.	
142	20 ,,	12. (noon)	·00	·00	18·8 (66)	14·4 (58)	21·6 (71)	8 3 (47)	1·75	Final effluent.	
143	21 ,,	12. (noon)	·00	·00	22·2 (72)	16·1 (61)	23·3 (74)	12·7 (55)	1·50	Final effluent.	
144	22 ,,	12. (noon)	·00	·00	22·2 (72)	17·2 (63)	23·8 (75)	13·3 (56)	·75	Final effluent.	
144A	23 ,,	12. (noon)	·00	·00	18·3 (65)	17·2 (63)	21·6 (71)	10·5 (51)	—	Final effluent.	
145	24 ,,	12. (noon)	·00	·02	15·5 (60)	13·8 (57)	20· (68)	3·8 (39)	2·	Final effluent.	
146	25 ,,	12. (noon)	·02	·00	18·3 (65)	16·1 (61)	16·1 (61)	6·6 (44)	·25	Final effluent.	
147	26 ,,	12. (noon)	·00	·06	15·0 (59)	13·3 (56)	18·8 (66)	11·6 (53)	2·	Final effluent.	
148	27 ,,	12. (noon)	·06	·04	17·7 (64)	14·4 (58)	20· (68)	13·3 (56)	2·50	Final effluent.	
						END OF EXPERIMENT					
	1901										
349	30 September	11.30 a.m.	·00	·00	18·8 (66)	17·7 (64)	21·1 (70)	12·2 (36)		Screened Sewage.	
350	30 ,,	12. (noon)	·00	·00	18·8 (66)	21·1 (70)	21·1 (70)	12·2 (36)		First field effluent.	
351	30 ,,	12.30 p.m.	·00	00	19·4 (67)	15·5 (60)	21·1 (70)	12·2 (36)		Second field effluent.	
352	30 ,,	1.00 p.m.	·00	·00	19·4 (67)	15· (59)	21·1 (70)	12·2 (36)		Final effluent.	
353	1 October	11.30 a.m.	·00	·03	18·3 (65)	13·3 (56)	20· (68)	6·6 (44)		General effluent.	
354	1 ,,	11.45 a.m.	·00	·03	18·3 (65)	15· (59)	20· (68)	6·6 (44)		General effluent.	
354A	1 ,,	—	—	—	—	—	—	—		Screened Sewage.	
355	1 ,,	12. (noon)	·00	·03	19·4 (67)	17·7 (64)	20· (68)	6·6 (44)		Screened and settled sewage.	Mean daily max. temp. 19·3° C. (66·8) °F.
356	1 ,,	1.00 p.m.	·00	·03	20·0 (68)	15· (59)	20· (68)	6·6 (44)		General effluent.	Mean daily min. temp. 6·5° C. (43·8) °F.
357	2 ,,	11.15 a.m.	03	·005	16·6 (62)	18·3 (65)	20· (68)	10· (50)		Screened and settled sewage.	Mean daily rainfall ·035 in.
358	2 ,,	11.30 a.m.	·03	·005	16·6 (62)	18·3 (65)	20· (68)	10· (50)		First field effluent.	For the period September 30th to October 4th, 1901.
359	2 ,,	12.30 p.m.	·03	·005	16·6 (62)	16·1 (61)	20· (68)	10· (50)		Second field effluent.	
360	2 ,,	1.00 p.m.	·03	·005	17·2 (63)	16·6 (62)	20· (68)	10· (50)		Final effluent.	
361	3 ,,	10.30 a.m.	·005	·00	15·5 (60)	18·3 (65)	18·3 (65)	6·6 (44)		Screened and settled sewage.	
362	3 ,,	11.15 a.m.	·005	·00	18.8 (66)	20·0 (68)	18·3 (65)	6·6 (44)		First field effluent.	
363	3 ,,	12.15 p.m.	·005	·00	17·7 (64)	16·6 (62)	18·3 (65)	6·6 (44)		Final effluent.	
364	3 ,,	12.45 p.m.	·005	·00	16·1 (61)	16·1 (61)	18·3 (65)	6·6 (44)		General effluent.	
365	4 ,,	11.00 a.m.	·00	·14	13·8 (57)	17·4 (64)	17·2 (63)	7·2 (45)		Screened and settled sewage.	

LEICESTER SEWAGE FARM—*continued.*

TABLE I—*continued.*

(Domestic Sewage and Trade Refuse.)

Number of Sample.	Date of Drawing Sample.	Time of Day.	Rainfall Day previous to drawing Sample.	Rainfall Day of drawing Sample.	Air Temperature time of drawing Sample.	Temperature of Sample.	Maximum Temperature during the 24 hours.	Minimum Temperature during the 24 hours.	Humidity (9 a.m.)	Dissolved Oxygen in Sample.	Brief Description of Sample.	Remarks.
	1899		Inches.	Inches.	°C. °F.	°C. °F.	°C. °F.	°C. °F.				
366	4 October -	11.30 a.m.	·00	·14	13·8 (57)	12·2 (54)	17·2 (63)	7·2 (45)			First field effluent.	
367	4 ,, -	12.30 p.m.	·00	·14	13·3 (56)	12·2 (54)	17·2 (63)	7·2 (45)			Final effluent.	
368	4 ,, -	1.00 p.m.	·00	·14	13·3 (56)	12·7 (55)	17·2 (63)	7·2 (45)			General effluent.	
	1902											
469	11 February -	12 30 p.m. Mon. to 11.30 a.m. Tues.	3 in. snow	·00							Screened and settled sewage.	24 hours samples.
470	12 , -	12.30 p.m. Tues. to 11.30 a.m. Wed.	·00	·00							Screened and settled sewage.	
471	13 ,, -	12.30 p.m. Wed. to 11.30 a.m. Thurs.	·00	·00							Screened and settled sewage.	

LEICESTER SEWAGE FARM.

TABLE II.

(Domestic Sewage and Trade Refuse.)
Table of Samples other than Sewage.

Number of Sample.	Number of Times the Sewage was passed over the Soil.	Area of Plot or Plots Sewaged at the time of Drawing Sample.	Length of Time those Plots had been Sewaged previously to Drawing Sample.	Nature of Crops Grown on Plots.	Remarks.
		Acres.			
2	once	13·59	*38 days	Arable—no crops	Sample consisted of surface and filtration effluent.
3	three times	14·59 11·30	38 days	Permanent pasture	Very slight sewage smell; rain during drawing of samples stirred up sediment on fields somewhat. Surface effluent.
4	twice	8·57 16·90	27 days	Arable and permanent pasture	General effluent, slight sewage smell.
5					Subsoil water, drawn 7ft. 6in. deep from sand partings in the Boulder clay, chalky appearance.
6					Water from the Anstey brook, drawn below outfalls Nos. 1 and 2. (Brook rather high).
8	once	6·87	32 days	Arable—no crops	*Slight sewage smell. Surface effluent and filtration effluent All fields sewaged continuously, both day and night.
9	twice	10·7	32 days	Permanent pasture	Surface and filtration effluent, very little smell.
125	once	6·34	12 days	No crops	Surface and filtration effluent, slight sewage smell.
126	twice	16·90	12 days	Permanent pasture	Surface and filtration effluent, very slight sewage smell.
127A	once	19·18	13 days	Fallow—no crops	Surface and filtration effluent, slight sewage smell.
127B					Water from Anstey brook above the effluent outfalls. (Brook rather low.)
127	twice	22·25	13 days	Permanent pasture	Surface and filtration effluent.
128A	once	19·18	18 days	Fallow—no crops	,, ,, ,,
129	twice	22·25	13 days	Permanent pasture	,, ,, ,,
130A					Water from Anstey brook above the effluent outfalls, volume of brook about 1·5 million gallons per 24 hours.
130					General effluent.
131	twice	19·18 22·25	21 days 21 days	Fallow and permanent pasture	Surface and filtration effluent (final), sewage smell.
132					General effluent about 1,000,000 gallons flowing per 24 hours.
133					Water from Anstey Brook above effluent outfalls; brook about normal.
134					Effluent and brook water 50 yards below Sample No. 132.
135					Effluent and brook water 600 yards below Sample No. 134.
137	twice	6·5 10·5	1 day	Fallow and permanent pasture.	Filtration sample, no surface effluent.
138	,,	,,	2 days	,, ,,	Filtration and surface effluent.
139	,,	,,	7 days	,, ,,	,, ,, ,, after fields had received a soaking of sewage.
140	,,	,,	8 days	,, ,,	Filtration and surface effluent.
141	,,	,,	9 days	,, ,,	,, ,, ,,
142	,,	,,	10 days	,, ,,	,, ,, ,,
143	,,	,,	11 days	,, ,,	,, ,, ,,
144	,,	,,	12 days	,, ,,	,, ,, ,, Effluent very bad.
144A	,,	,,	13 days	,, ,,	Filtration and surface effluent.
145	,,	,,	14 days	,, ,,	,, ,, ,,
146	,,	,,	15 days	,, ,,	,, ,, ,,
147	,,	,,	16 days	,, ,,	,, ,, ,,
148	,,	,,	17 days	,, ,,	,, ,, ,,

LEICESTER SEWAGE FARM.—*Cont.*

TABLE II.—*Cont.*

Table of Samples other than Sewage—*Cont.*

Number of Sample.	Number of Times the Sewage was passed over the Soil.	Area of Plot or Plots Sewaged at the time of Drawing Sample.	Length of Time those Plots had been sewaged previously to Drawing Sample.	Nature of Crops Grown on Plots.	Remarks.
		Acres.			
350	once	19·28	20 days	Fallow; no crops	Surface effluent, sewage smell.
351	twice	12·77	21 days	Rye grass and permanent pasture.	Surface effluent.
352	3 times	5·88	10 days	Permanent pasture.	Surface effluent, a clear sample.
353	2–3 times			Fallow and permanent pasture.	Surface effluent. General effluent.
354				,, ,,	,, ,, ,, ,,
356				,, ,,	,, ,, ,, ,,
358	once	19·28	22 days	Fallow; no crops	Surface effluent.
359	twice	12·77	23 days	Fallow, Rye, and permanent pasture.	,, and filtration.
360	3 times	5·88	12 days	,, ,,	,, ,, ,,
362	once	19·28	23 days	Fallow; no crops	Surface effluent.
363	3 times	12·77 / 5·88	13 days	Fallow, Rye, and Permanent Pasture	Surface and filtration effluent.
364				,, ,,	Surface and filtration effluent. Gener effluent.
366	once	19·28	24 days	Fallow ; no crops	Surface effluent.
367	3 times	12·77 / 5·88	14 days	Fallow, Rye, and Permanent Pasture	Surface and filtration effluent.
368				,, ,,	Surface and filtration effluent. Gener effluent.

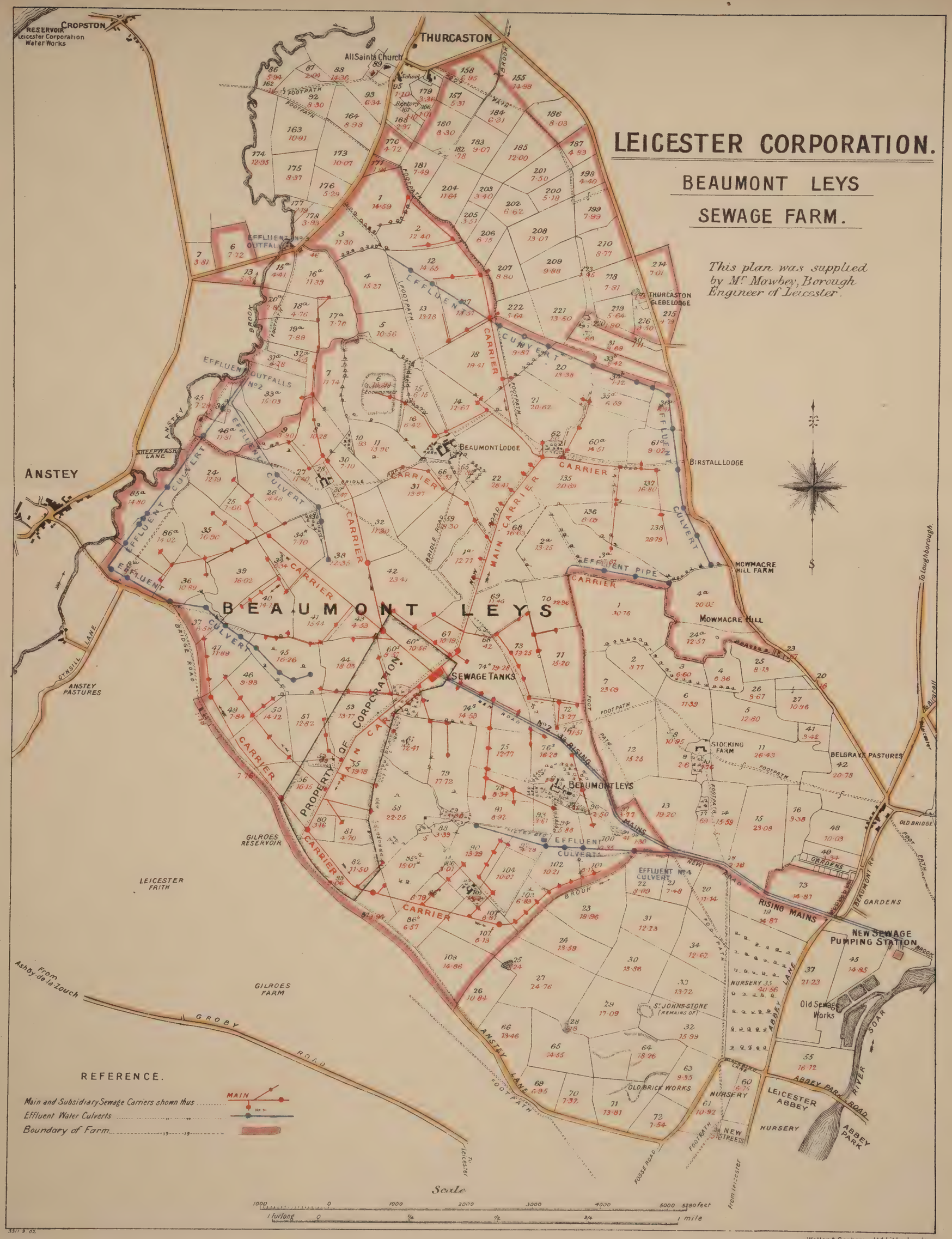
LEICESTER SEWAGE FARM.

TABL —III.

Comparative Samples ;

or Samples taken from the same plots of land.

First (or arable) field effluents.	Second field (pasture or Rye Grass) effluents.	Final effluents.	Remarks.
No. (127A). ,, (128A).		No. (127). ,, (129). ,, (131).	* By Comparative Samples is meant Sample drawn from the same areas of land, and the effluents in brackets are comparable with each other so far as the area of land sewaged is concerned.
No. (350). ,, (358). ,, (362). ,, (366).	No. (351). No. (359).	No. (352). ,, (360).† ,, (363). ,, (367).	† Samples Nos. 352-367 were treated on (or had passed over) 3 fields.


LEICESTER CORPORATION.
BEAUMONT LEYS
SEWAGE FARM.
This plan was supplied by Mr. Mawbey, Borough Engineer of Leicester.
CROPSTON
RESERVOIR
Leicester Corporation Water Works
THURCASTON
All Saints Church
ANSTEY
BEAUMONT LEYS
BEAUMONT LODGE
BIRSTALL LODGE
THURCASTON GLEBE LODGE
MOWMACRE HILL FARM
MOWMACRE HILL
SEWAGE TANKS
PROPERTY OF CORPORATION
BEAUMONT LEYS
STOCKING FARM
BELGRAVE PASTURES
GILROES RESERVOIR
LEICESTER FRITH
GILROES FARM
ANSTEY PASTURES
GROBY ROAD
From Ashby-de-la-Zouch
To Leicester
From Leicester
To Loughborough
To Birstall
NEW SEWAGE PUMPING STATION
Old Sewage Works
LEICESTER ABBEY
ABBEY PARK
ST. JOHNS STONE (REMAINS OF)
OLD BRICK WORKS
NURSERY
NEW STREETS
GARDENS
OLD BRIDGE
RISING MAINS
EFFLUENT CULVERT
EFFLUENT PIPE
MAIN CARRIER
CARRIER
EFFLUENT OUTFALLS No. 2
EFFLUENT OUTFALL No. 3
EFFLUENT No. 4 CULVERT
SHEEPWASH LANE
ANSTEY LANE
ABBEY LANE
ABBEY PARK ROAD
RIVER SOAR
BEAUMONT RD
FOOTPATH
BRIDLE ROAD
FOSSE ROAD
BROOK
REFERENCE.
Main and Subsidiary Sewage Carriers shown thus
Effluent Water Culverts
Boundary of Farm
MAIN
Scale
1000 0 1000 2000 3000 4000 5000 5280 feet
1 furlong 0 1/4 1/2 3/4 1 mile
Weller & Graham Ltd Litho. London.

Addendum B

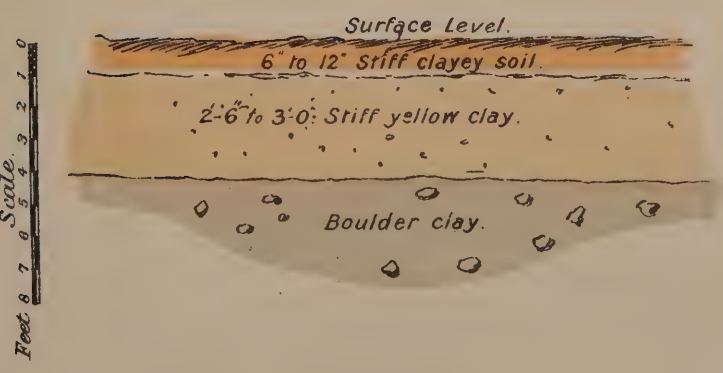
I.

LEICESTER SEWAGE FARM.
BEAUMONT LEYS.

Scale-Six Inches to one Mile.

BROOK SAMPLES.

SECTION OF SOIL & SUBSOIL.

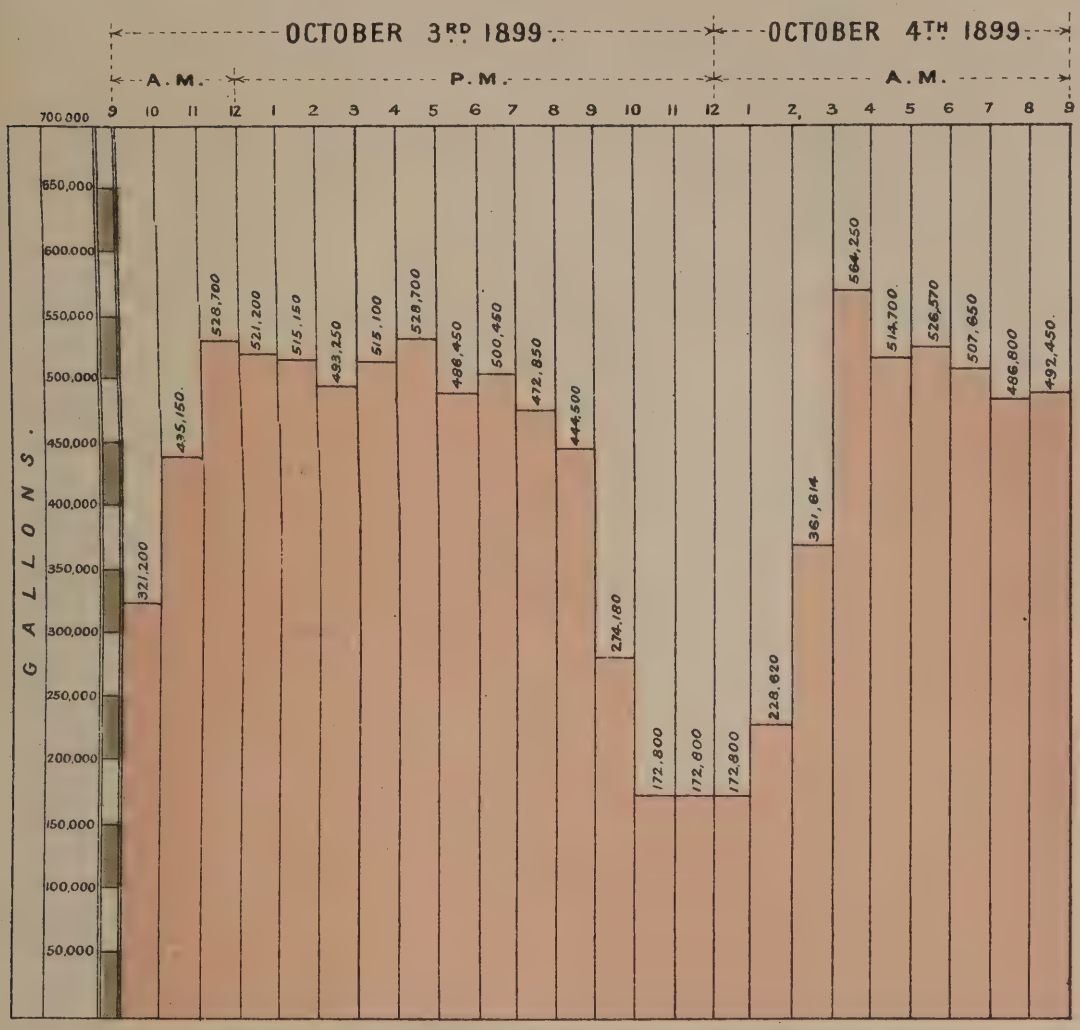


Weller & Graham Ltd Litho. London.

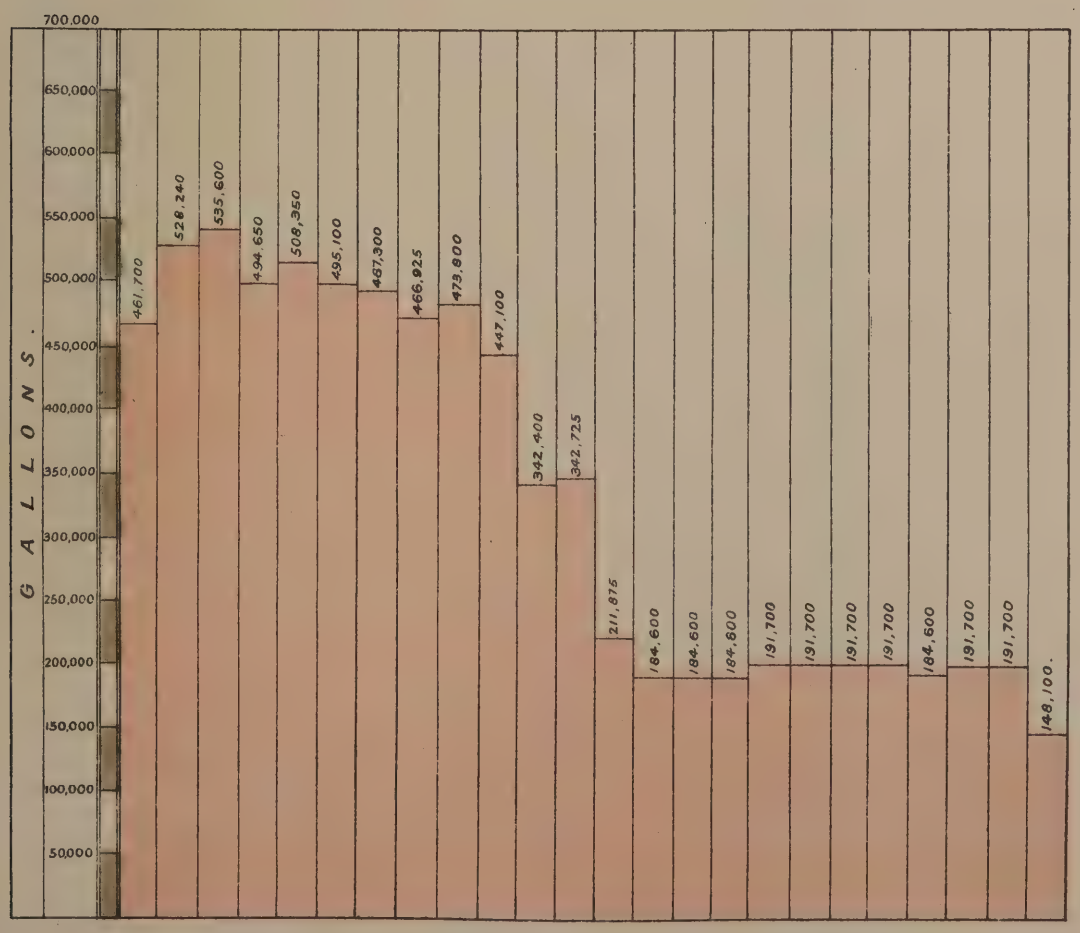
CORPORATION OF LEICESTER.

BEAUMONT LEYS PUMPING STATION.

Diagram shewing volume of Sewage pumped per 24 hours.



NOTE :- Rainfall during the above period 0·14.



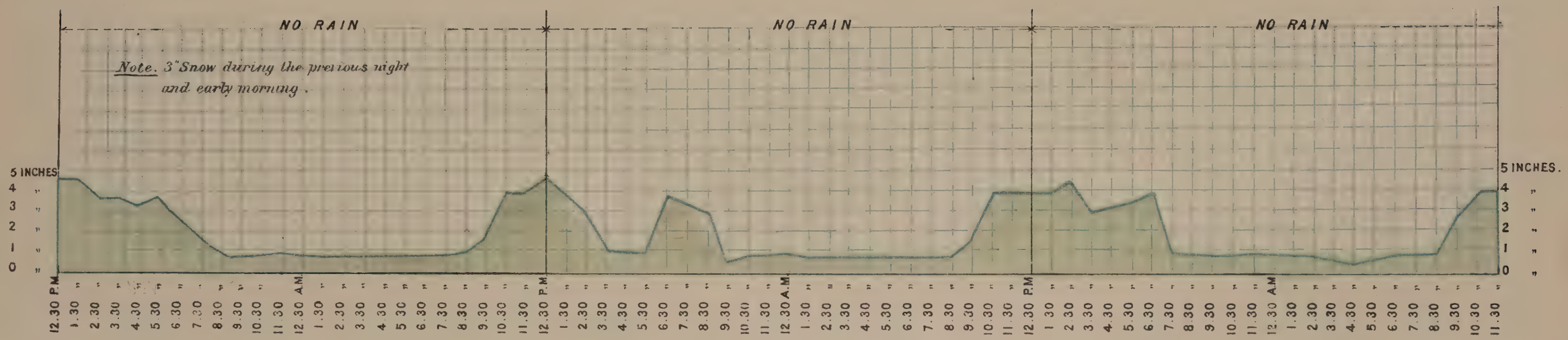
NOTE :- No rainfall during the above period.

These diagrams were supplied by Mr Mawbey. Borough Engineer of Leicester.

Weller & Graham Ltd Litho. London

LEICESTER SEWAGE FARM.

Diagram shewing hourly depths of sewage passing over tank sills during 3 days.



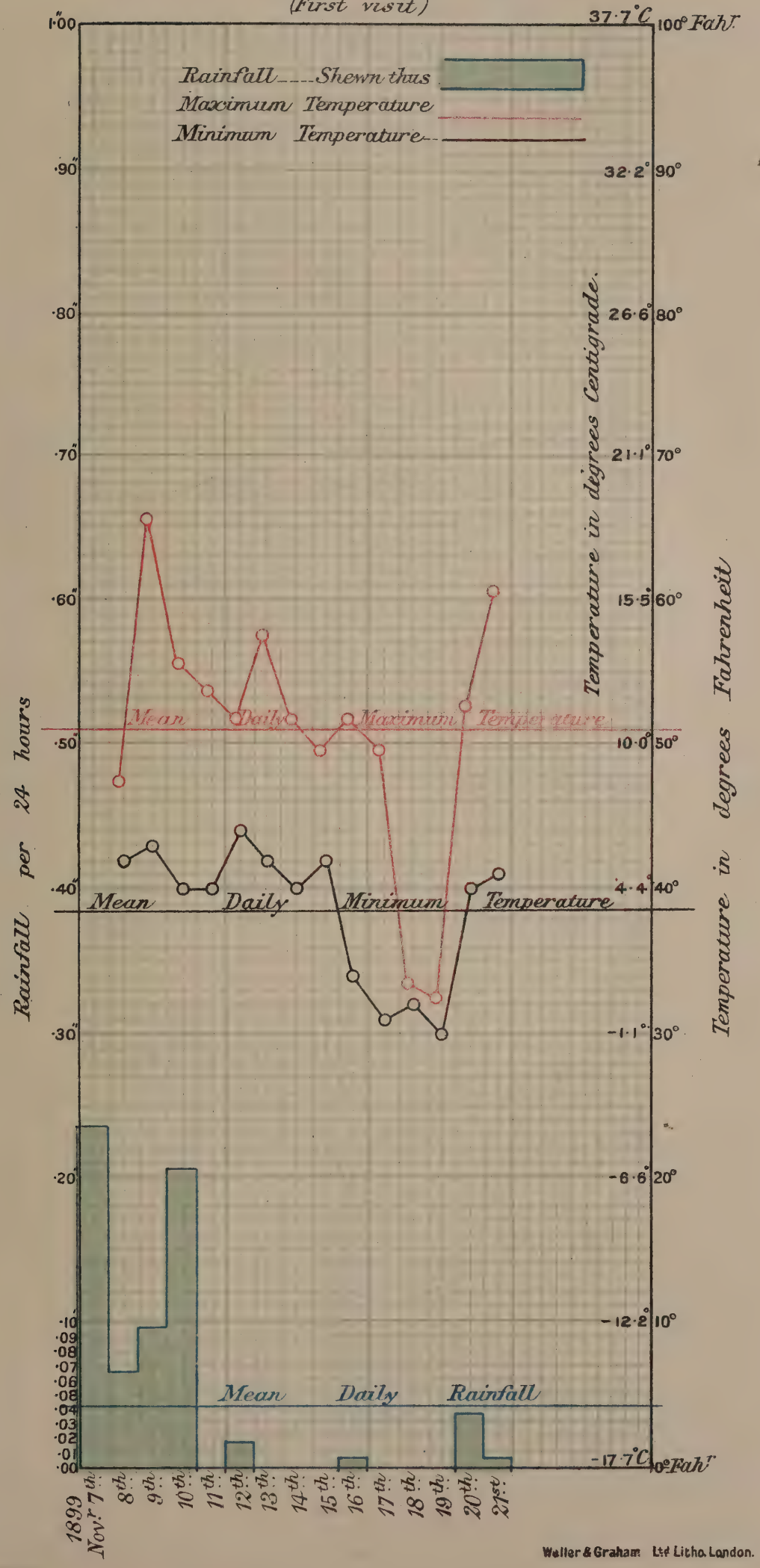
3318. 9. 02.

Weller & Graham Ltd Litho. London.

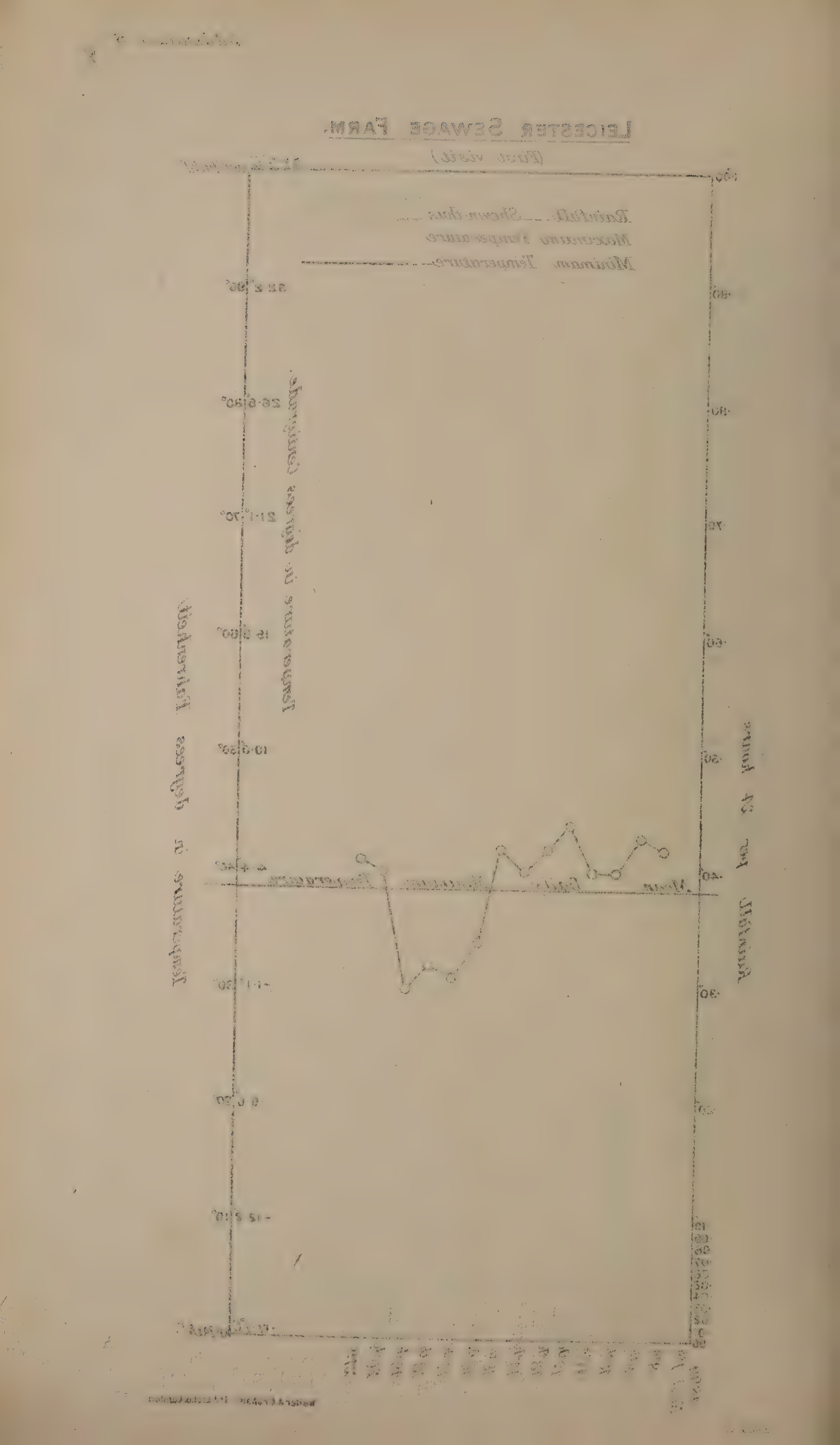
Addendum B. IV.

LEICESTER SEWAGE FARM.

(First visit)

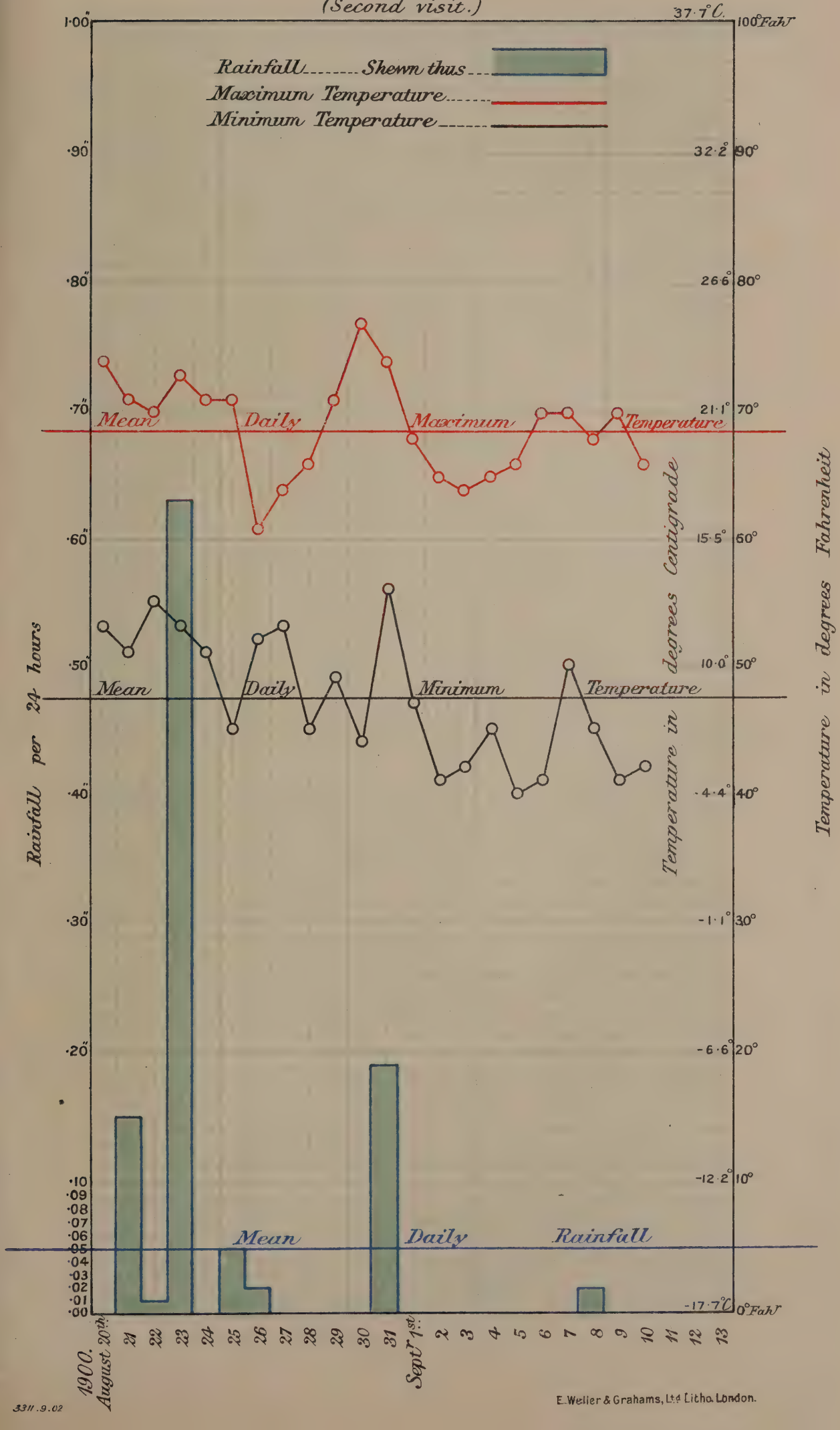


Waller & Graham Ltd Litho. London.



LEICESTER SEWAGE FARM.

(Second visit.)

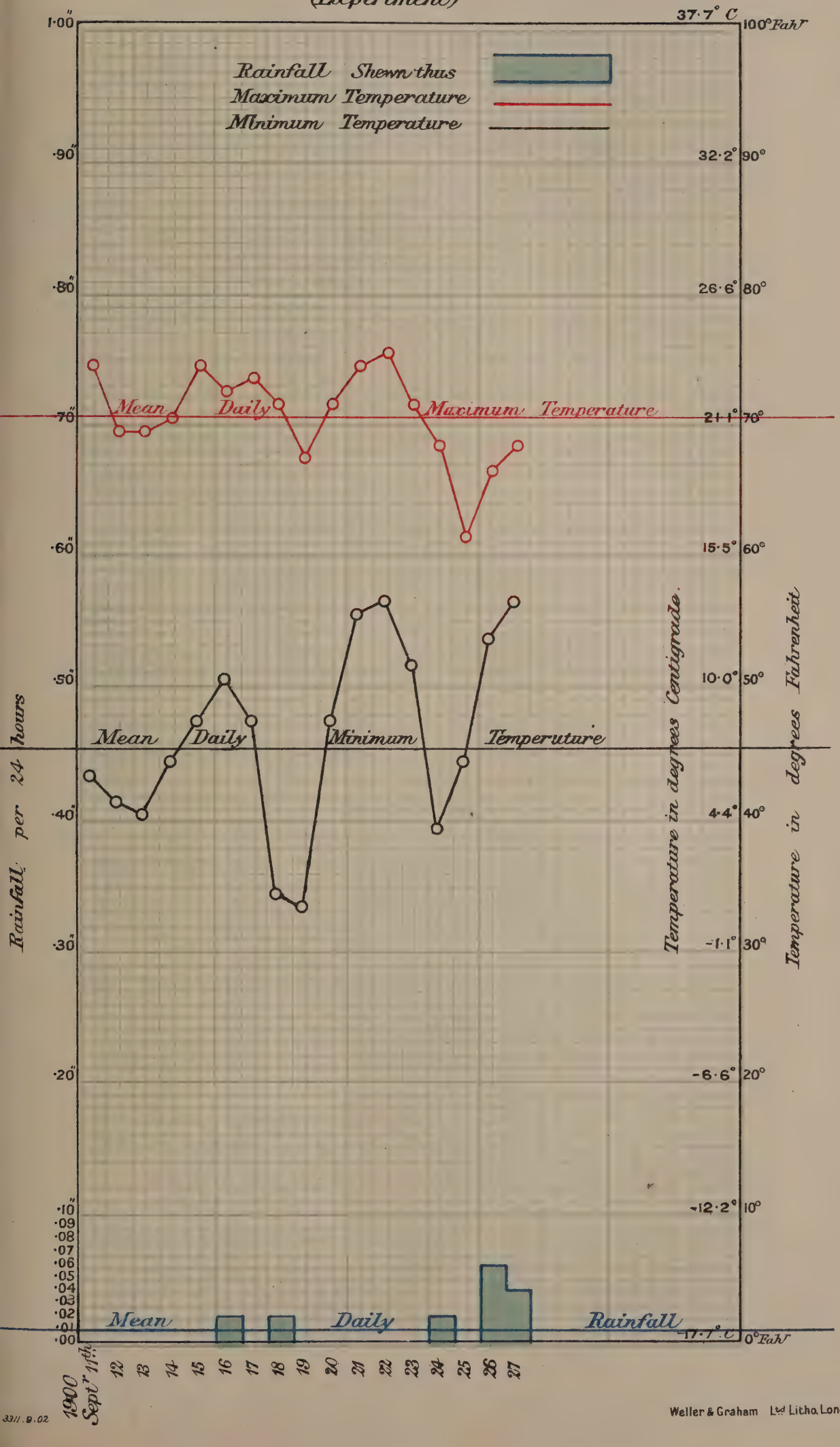


3311.9.02

E. Weller & Grahams, Ltd Litho. London.

LEICESTER SEWAGE FARM.

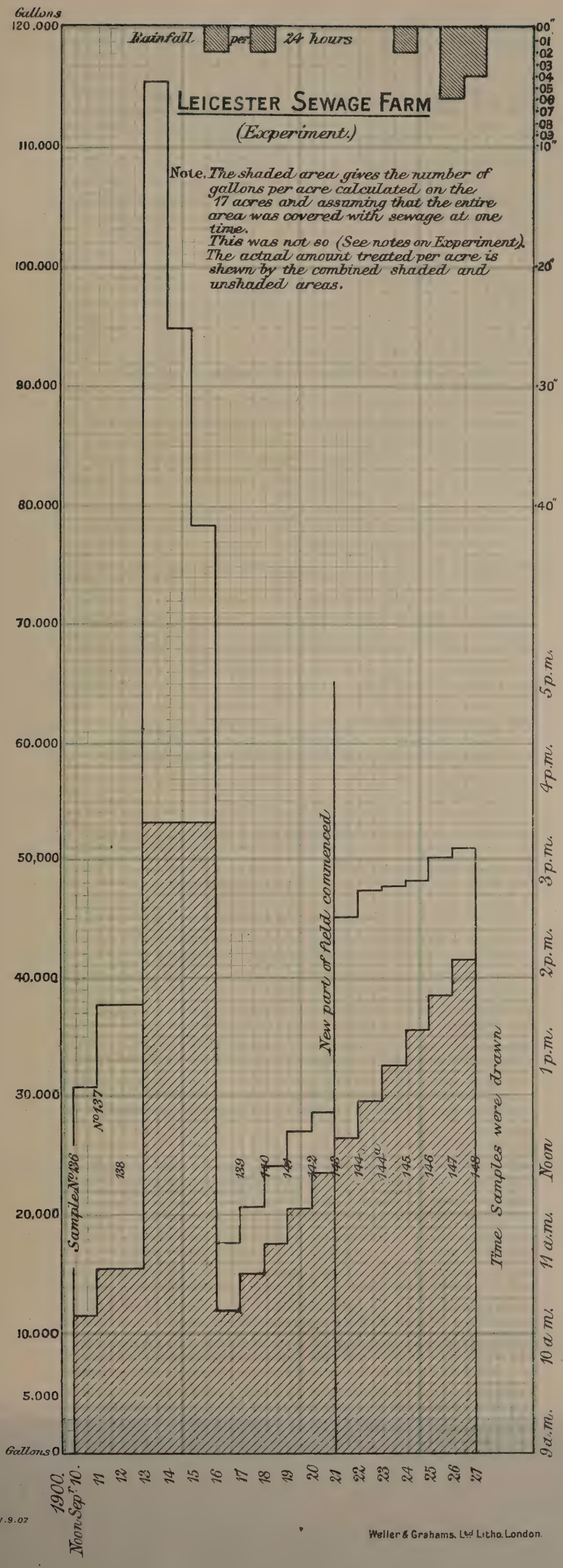
(Experiment)



3311.9.02

Weller & Graham Ltd Litho. London.

Addendum B
VIII.



3311.9.02

Weller & Grahams, Ltd Litho. London.

NOTTINGHAM SEWAGE FARM (Stoke Bardolph).

(Nottingham Corporation).

1. Situation of farm—Stoke Bardolph, about 5 miles from Nottingham.

2. Total acreage of farm—907 acres (1900).

3. Total irrigable area—651 acres (1900).

4. Average area irrigated at one time—300 acres.

*5. Population draining to farm—258,584.

6. ,, per acre irrigated—397.

7. Gallons of sewage per head per day—27.

8. Dry weather flow of sewage per 24 hours—7,000,000 gallons.

9. Gallons of sewage (exclusive of storm water) treated per acre per 24 hours—23,300 = ($\frac{7000000}{300}$).

10. Gallons of sewage treated per acre per 24 hours, on the assumption that each acre of irrigable area is under sewage all the time. This for purposes of comparison—$\frac{7000000}{651}$ = 10,750 gallons.

11. Characters of the sewage—$\frac{4}{7}$ domestic, $\frac{3}{7}$ trade refuse.

12. Method of treatment—Screening (partial), and land filtration.

13. General characters of the soil and subsoil—Light sandy loam and gravel overlying gravel and sand.

14. Separate or combined sewerage system—Combined.

15. The final effluent is discharged into—River Trent.

16. Number of years farm in operation before 1900—19½ years.

* It will, however, be seen from the following description of the farm (page 67) that a large proportion of the fæcal matter is kept out of the sewers.

NOTTINGHAM SEWAGE FARM REPORT.

SUMMARY OF CONTENTS.

DESCRIPTION OF FARM.

Addendum A.—Notes on Samples.

Additional Notes on Samples.

Table I.—Shewing all samples drawn at the Nottingham Sewage Farm, together with time of drawing, rainfall, temperatures, description of samples, etc.

Table II.—Giving area of plots from which effluents were drawn, and the time those plots had been under sewage, etc.

Table III.—Comparative effluent samples.

Table IV.—Sewage samples.

Addendum B.—Plans and diagrams referred to in report.

I.—Plan of farm.

II.—Plan shewing where river samples were drawn, and section of soil and subsoil.

III.—Temperature and rainfall chart—(1st visit).

IV.— " " " " (2nd visit).

NOTTINGHAM SEWAGE FARM (Stoke Bardolph).

(Nottingham Corporation.)

Domestic Sewage—Trade Refuse.

This sewage contains a large quantity of manufacturing refuse, and is treated by means of screening (partial) and land filtration.

This soil on the farm varies somewhat (Add. B. II.). For the most part there is from 7 inches to 15 inches surface soil of a light, porous, sandy loam, interspersed with and overlying river valley gravel and sand, and admirably adapted for sewage filtration; some portions of the land are of a rather heavier nature.

The farm is managed by the Nottingham Corporation, and has been in use for 19½ years (1900). The irrigation land is not liable to floods.

There is, practically, no subsoil water on the farm at the depth at which the underdrains are laid.

The volume of domestic sewage and trade refuse combined is (1900) about 7,000,000 gallons (or about 27 gallons per head). Approximately, three-sevenths of the total consists of refuse from bleach, dye, and bone works, wool-scouring, breweries, laundries, and fellmongers. The bleach and dye refuse preponderates. The refuse is not treated by the manufacturers previously to entering the sewers. The present powers with regard to manufacturers are considered insufficient. The area of the city is 10,935 acres, with a rateable value of 907,000*l.*, the estimated population up to July being 239,384. The districts draining to the sewage farm and their populations are given below :—

Nottingham	239,384
Arnold	10,000
Carlton	9,200
Total population draining to sewage farm	258,584

The public water supply is about 20 gallons per day in summer and about 16½ gallons in winter, obtained from deep wells in the new red sandstone.

The average annual rainfall at Nottingham for the past 32 years is 25 inches.

The number of w.c's connected to the sewerage system is :—

Nottingham	10,703
Arnold	80
Carlton	67
Total	10,850

There is a large number of tub closets and waste water closets in the poorer districts. Altogether there are 40,550 tub closets, 2,334 waste water closets or slop closets, and 300 midden privies.

The City Medical Officer of Health, Dr. Boobbyer, has arrived at the conclusion that the incidence of typhoid on these districts is far greater than in other parts of the city. In the case of the tub closets the greater part of urine is emptied down the back yard gullies and goes to the sewers. Where tub closets are in use the night soil containing the fæces is taken to the depôts, tipped in barges, and distributed among the farmers. There are 6,851 baths which discharge into the sewers, Nottingham having 6,565, and Arnold and Carlton 89 and 197 each respectively. The sewerage system is mainly of modern construction. The main intercepting and outfall sewers are of recent date, and it was stated that there are now very few sewers in a faulty condition; these are gradually being taken out and reconstructed, and consequently there is little subsoil leakage to the sewers. In the low-lying districts of the city the sewers are flushed systematically by means of movable flushing tanks. A large number of the Nottingham streets are not macadam, but paved with stone setts, a fact which probably partly accounts for the comparative absence of sludge on the farm.

There is no separate system, all the storm and surface water going to the foul water sewers. About two-thirds of the total sewage flow, or $4\frac{1}{2}$ million gallons, is pumped to a chamber on the outfall sewer, half a mile from the pumping station. At this chamber it joins the remainder of the sewage, which gravitates to this point. From this chamber the whole of the sewage flows by gravitation to the sewage farm. Before reaching the pumps, the former sewage is passed through a screen consisting of upright bars set 1 inch apart to arrest matter likely to injure the pumps. The sewage gravitating to the farm is not screened in any way. The pumping plant consists of two Gwynne & Co.'s 22-inch vertical compound jet condensing centrifugal pumps, one working, the other kept in reserve. The sewage is lifted about 15 feet. The centrifugal pumps have the effect of breaking up the solids in the sewage considerably. The time taken by the sewage to reach the pumping station from the centre of the city is about 1 hour, and the time taken from the pumping station to the farm is about 2 hours, the distance to the farm from the pumping station being about $3\frac{1}{2}$ miles. The size of the main outfall to the farm is 5 feet 3 inches by 5 feet, laid at a gradient of 1 in 2,455, and having a capacity when running full of 2,698 cubic feet a minute.

There are four storm overflows, one discharging into the River Leen and three into the River Trent. They come into operation when the rainfall exceeds $\frac{1}{4}$ inch in the 24 hours. The sewage on reaching the farm is distributed along main carriers constructed of concrete and provided with wooden sluices; these carriers pass under the farm roads by means of inverted syphons. The subsidiary carriers are all earthen, and formed in the soil by the plough; an electric alarm warns the watermen when the main carrier is running full. The sewage is only treated through the soil once. The maximum and strongest flow is from about 9 a.m. to 2 p.m. The total area of the farm is (1900)* 907 acres (Add. B. I.). Of this area about 245 acres are pasture land and 615·25 acres arable. The total area actually irrigated is 615·25 acres of arable and 35·75 acres of pasture land. This area of 651 acres deals with (excluding storm water) 7,000,000 gallons of sewage per 24 hours, which is equal to 107·53 gallons per acre, or 397 persons per acre approximately. About 300 acres are irrigated at one time, which corresponds to 23,300 gallons treated per acre per 24 hours.

The entire farm is underdrained by 4-inch agricultural pipe feeders laid herringbone into 12-inch socketted pipe mains, which in turn are connected where necessary into larger pipe mains. The feeder drains are laid from 4-feet 6 inches to 7 feet 6 inches deep The main drains are laid from 6 feet to 10 feet deep. Upon an area of 120 acres—referred to hereafter as the "closely drained area"—the main drains are laid at a distance of 66 feet apart and the 4-inch feeders 33 feet apart.† On the remainder of the farm the main drains are 132 feet apart and the feeders 66 feet. The main drains vary from 12 inches to 24 inches in diameter, plain sockets. The feeders are all 4-inch agricultural pipes, butt jointed, without sockets. Turfing is placed over all the joints, and the soil from the trench is again filled in. Great care is taken to well ram all the filling. When the drains were laid the trenches throughout were quite dry and did not require timbering, except where they were below the level of the River Trent. The method of irrigation is as follows:—About 300 acres are used per 24 hours. This total, broadly speaking, is made up of (1) 250 acres of land which are used on the 12 hours system about to be described; (2) about 50 acres of the 120 acres referred to previously as the "closely drained area" which are employed for increases in the sewage flow. (1) The sewage is run continuously in periods of 12 hours on to each half (125 acres) alternately of the 250 acres above mentioned. Thus each half (125 acres) is allowed a resting period of 12 hours. About 50 acres of the "closely drained area" are sewaged continuously, until the land shows signs of becoming over-sewaged. When this takes place a portion of the remaining 70 acres is brought into use. Approximately, the same land is sewaged for about one month before the sewage is taken off. If, however, at the end of that time, the same area was continuing to produce a satisfactory effluent, it might be sewaged for a slightly longer period, or the sewage might be run on both day and night for the remainder of the time.

* To be increased to 1,946 acres on the extension of the farm, which will shortly take place.

† This area is not cropped as a rule, and is kept as frequently ploughed as possible.

The crops grown on the farm are mangolds, ryegrass, kohl rabi, thousand-headed kale, ox and market cabbage, swedes, potatoes, wheat, oats, barley, and clover. Ryegrass, mangolds, and cabbage are the chief crops.

There are four effluent outfalls discharging into the River Trent. The main portion of effluent passes to the river by Carr Dyke. In the driest weather the volume of the River Trent at Nottingham is as low as 300,000,000 gallons per day. With a very small rise this is increased to 1,000,000,000 gallons, and with a rise of about 4 feet above low-water level the volume is as much as 2,000,000,000 gallons per day. From this it appears that the volume of the Trent in ordinary weather is from 40 to 300 times the volume of the effluent from the farm. It may be mentioned here that the Trent receives the sewage from most of the populous villages on the banks, excepting Arnold, Carlton and Beeston. The sewage from Radcliffe flows untreated into the Trent a short distance above the Nottingham sewage farm, the ditch conveying the sewage to the river being (July 1900) in a filthy condition. The river below the effluent outfalls at the time of visiting the farm was, to all appearances, in good condition, and there appeared to be no sewage weed. There was no noticeable smell arising from the sewaging operations. Occasionally in hot weather the stirring up of the sewage in passing under the road syphons causes a slight smell, but only in the immediate vicinity. The effluents leaving the farm were invariably clear, colourless, and odourless. There is usually a small profit on the year's working of the farm, some part of the rent being made, in addition to paying for labour. This of course does not include interest on loan, pumping, or rent of farm.

Water and gas are laid on to all the farm buildings; a large herd of dairy cattle is kept, and the milk, etc., produced is sold. The farm is well-managed; six men are constantly employed in attending to and regulating the sewage.

As before stated, the farm is soon to be enlarged to more than double its present area, to avoid all risk of over-sewaging the land, the present area with the greatest care being barely sufficient for the present volume of sewage. This volume will be greatly increased shortly, as it is intended to deal with the bleach and dye refuse from the Radford and Basford districts situated in the River Leen Valley, which is at present discharged into the Leen. The present carriers on the farm are worked to their utmost capacity and frequently overflow at the period of maximum flow, consequently they can only deal with a small amount of storm water in addition to the sewage proper, about 10,000,000 gallons being the limit treated on the farm.

The syphon now in course of construction to feed the extension of the farm will relieve the old carriers of a large proportion of the sewage flow.

Notes on Temperature, Rainfall, Etc.

During the visit to the farm in December, 1899 (December 3rd to December 22nd) the mean daily minimum temperature in the shade was low, being −1·1°C. (29·9°F.) The lowest reading registered was −12·2°C. (10°F.) on December 15th. There were several very severe frosts, and on the 11th and 12th snow fell (·05 inch and ·04 inch). The mean daily rainfall amounted to ·036 inch, rain falling on 7 days out of 20—viz., December 3rd, 4th, 5th, 6th, 11th, 12th, and 18th. The greatest rainfall was ·24 inch on the 5th. The mean daily maximum temperature in the shade was 3·8°C. (39°F.), the highest reading being 12·2°C. (54°F.) on December 4th and 9th, and the lowest on December 10th, when −1·1°C. (30°F.) was registered, or 1·1°C. (2°F.) below freezing point. (Add. B. III. & IV.).

During the summer visit (July 22nd to August 8th 1900) the mean daily minimum was 12·3° C. (54·2° F.) and the mean daily maximum 23·1° C. (73·7° F.) The highest maximum reading was 30·5° C. (87° F.) on July 25th. The rainfall during this visit was very heavy, rain falling on 11 out of 18 days, bringing the mean daily rainfall up to ·19 inches. A very heavy thunderstorm occurred on the afternoon of August 6th, returning again the same evening, the total rainfall during the 24 hours being 1·25 inches. Another heavy downfall (·54 inches) took place on July 27. Excluding these two instances just mentioned, rainfall exceeding ·20 inches in the 24 hours fell on five days.

The maxima, minima, and rainfall were taken at the farm at 9 a.m. daily, the rainfall being entered to the previous day. (*See* Add. B. III., IV. & V.)

Addendum A.

Additional Notes on Samples.

Sample No. 11.—The plot from which this effluent was drawn was purposely sewaged very heavily night and day in order to obtain a bad effluent; and after a sample had been drawn of this effluent the plot was sewaged 12 hours by night only for 7 days when sample No. 14 was drawn; the object in view being to ascertain how long the land took to recover its purifying properties.

Sample No. 15.—The field from which this sample was drawn was under ice at the time, the sewage continuing to flow underneath.

Samples Nos. 16 and 19.—These samples were from a plot which had been sewaged with day sewage only, for 12 hours each day. The plot referred to was rested for 3 days between the two Samples Nos. 16 and 19.

Sample No. 112.—River Trent water taken above sewage farm. River rather low for the time of year, a fairly clear sample. The river appeared to be in good condition.

Sample No. 117.—River Trent water taken above farm. River rather high, water rather discoloured owing to flood water.

Sample No. 120.—River Trent water taken above effluent outfall. River high and water discoloured. (Addendum B. II.).

Sample No. 122.—River Trent water and effluent on mixing, taken 50 yards below No. 121. Ratio of effluent to river water as 1 to 160 (approximately).

Sample No. 123.—As above, but taken 120 yards below No. 122.

Sample No. 330.—A very clear effluent.

Sample No. 331.—As above.

Sample No 332.—General effluent; some decayed leaves, &c., from neighbouring hedges had blown into the main effluent culvert, from which the sample was drawn.

Sample No. 333—As above. A drinking place for cattle in the effluent culvert had been used earlier in the day.

Sample Nos. 340, 341, 346.—General effluents. All containing bits of decayed leaves previously alluded to. All the final effluents were clear, colourless, and odourless.

TABLE I.

(Domestic Sewage, and Bleach, Dye, Brewery, Laundry, Fellmongers', Woolscouring, and Bone Works Refuse.)

Number of Sample.	Date of drawing Sample.	Time of Day.	Rainfall day previous to drawing Sample.	Rainfall day of drawing Sample.	Air Temperature time of drawing Sample.	Temperature of Sample.	Maximum Temperature during the 24 Hours.	Minimum Temperature during the 24 Hours.	Humidity, 9 a.m.	Dis-solved Oxygen in Sample.	Brief description of Sample.	REMARKS.
	1899:		Inches.	Inches.	°C. °F.	°C. °F.	°C. °F.	°C. °F.				
10	5 December -	12 (noon).	·15	·24	9·4 (49)	15· (59)	9·4 (49)	8·3 (47)	—	—	Screened and crude sewage.	Heavy rainfall during the night.
11	5 ,, -	1.30 p.m.	·15	·24	—	8·8 (48)	9·4 (49)	8·3 (47)	—	—	Final effluent.	Mean maximum temperature, 3·8° C., (39° F.)
12	5 ,, -	1.35 ,,	·15	·24	—	11·1 (52)	9·4 (49)	8·3 (47)	—	—	,, ,,	Mean minimum temperature, - 1·1° C., (29·9° F.)
13	12 ,, -	12.15 ,,	·05 (snow).	·04 (snow).	—	15· (59)	- 1·1 (30)	·5 (33)	—	—	Screened and crude sewage.	Mean daily rainfall, ·036 in.
14	12 ,, -	12 (noon).	0·5 (snow).	·04 (snow).	—	9·4 (49)	- 1·1 (30)	·5 (33)	—	—	Final effluent.	(For the period December 3rd to December 22nd, 1901).
15	12 ,, -	12.30 p.m.	·05 (snow).	·04 (snow).	—	9·4 (49)	- 1·1 (30)	·5 (33)	—	—	,, ,,	Note.—Samples which may have been affected by rainfall or snow are underlined.
16	12 ,, -	3 ,,	·05 (snow).	·04 (snow).	17·2 (63)	10· (50)	- 1·1 (30)	·5 (33)	—	—	,, ,,	
17	19 ,, -	—	·04	·00	—	10· (50)	2·2 (36)	1·1 (34)	—	—	,, ,,	
18	20 ,, -	4 ,,	·00	·00	—	10· (50)	2·2 (36)	1·1 (34)	—	—	,, ,,	
19	20 ,, -	4 ,,	·00	·00	—	10· (50)	2·2 (36)	1·1 (34)	—	—	,, ,,	*Carrier overflowed during the night, and the area thus received more than its proper amount of sewage.
20	21 ,, -	3.45 ,,	·00	·00	—	8·8 (48)	2·7 (37)	1·1 (34)	—	—	* ,, ,,	
	1900:											
109	23 July - -	11.55 a.m.	·00	·00	25· (77)	20· (68)	29·4 (85)	17·2 (63)	—	—	Screened and crude sewage.	
110	23 ,, - -	2.15 p.m.	·00	·00	24·4 (76)	11·6 (53)	29·4 (85)	17·2 (63)	—	—	Final effluent.	
111	24 ,, - -	3 ,,	·00	·00	27.7 (82)	11·6 (53)	30· (86)	17·7 (64)	—	—	,, ,,	Mean maximum temperature, 23° C., (73·7° F.)
112	24 ,, -	4 ,,	·00	·00	27.7 (82)	22·2 (72)	30· (86)	17·7 (64)	—	—	River Trent water.	Mean minimum temperature 12·3° C., (54·2° F.)
113	25 ,, - -	11,45 a.m.	·00	·00	27·7 (82)	11·6 (53)	30·5 (87)	14·4 (58)	—	—	Final effluent.	Mean daily rainfall, ·19 in.
114	30 ,, - -	12.15 p.m.	·22	·00	19·4 (67)	16·6 (62)	22·2 (72)	10· (50)	—	—	Screened and crude sewage.	(For the period July 22nd to August 8th, 1900).
115	30 ,, - -	2.15 ,,	·22	·00	20· (68)	10·5 (51)	22 2 (72)	10· (50)	—	—	Final effluent.	
116	31 ,, -	11.45 a.m.	·00	·38	20· (68)	10·5 (51)	23·3 (74)	14·4 (58)	—	—	,, ,,	

TABLE I.—(*continued*)

(Domestic Sewage, and Bleach, Dye, Brewery, Laundry, Fellmongers', Woolscouring, and Bone Works Refuse—*continued*).

Number of Sample.	Date of drawing Sample.	Time of Day.	Rainfall day previous to drawing Sample.	Rainfall day of drawing Sample.	Air Temperature time of drawing Sample.		Temperature of Sample.		Maximum Temperature during the 24 hours.		Minimum Temperature during the 24 hours.		Humidity, 9 a.m.	Dissolved Oxygen in Sample.	Brief description of Sample.	Remarks.
	1900:		Inches.	Inches.	°C.	°F.	°C.	°F.	°C.	°F.	°C.	°F.				
117	31 July -	12.30 p.m.	·00	·38	21·6	(71)	18·8	(66)	23·3	(74)	14·4	(58)	—	—	River Trent water above farm.	
118	1 August -	11.30 a.m.	·38	·05	20·	(68)	12·7	(55)	21·1	(70)	12·2	(54)	—	—	Final effluent.	
119	1 „ -	11.45 „	·38	·05	20·	(68)	10·5	(51)	21·1	(70)	12·2	(54)	—	—	„ „	
120	6 „ -	11.30 „	·30	1·25	14·4	(58)	14·4	(58)	18·3	(65)	10·5	(51)	—	—	River water above effluent outfall.	
121	6 „ -	11.45 „	·30	1·25	15·	(59)	12·7	(55)	18·3	(65)	10·5	(51)	—	—	§General effluent.	
122	6 „ -	12 (noon)	·30	1·25	13·8	(57)	14·4	(58)	18·3	(65)	10·5	(51)	—	—	River water and general effluent.	
123	6 „ -	12.30 p.m.	·30	1·25	13·3	(56)	14·4	(58)	18·3	(65)	10·5	(51)	—	—	„ „ „	
	1901:															
329	23 September	1.50 p.m.	·01	·00	20·	(68)	19·4	(67)	19·4	(67)	12·2	(54)	—	—	Screened and crude sewage.	
330	23 „ -	2.20 „	·01	·00	20·	(68)	13·3	(56)	19·4	(67)	12·2	(54)	—	—	Final effluent.	
331	23 „ -	2.30 „	·01	·00	19·4	(67)	13·3	(56)	19·4	(67)	12.2	(54)	—	—	„ „	Mean maximum temperature, 20·1 C. (68·25° F.)
332	23 „ -	2.45 „	·01	·00	19·4	(67)	13·3	(56)	19·4	(67)	12·2	(54)	—	—	General effluent.	Mean minimum temperature, 10°. C. (50° F.)
333	24 „ -	11.30 a.m.	·00	·00	15·5	(60)	13·3	(56)	19·4	(67)	11·1	(52)	—	—	„ „	Mean daily rainfall, ·00 in.
334	24 „ -	11.35 „	·00	·00	15·5	(60)	19·4	(67)	19·4	(67)	11·1	(52)	—	—	Screened and crude sewage.	(For the period September 23rd to September 26th, 1901.
335	24 „ -	11.45 „	·00	·00	15·5	(60)	13·3	(56)	19·4	(67)	11·1	(52)	—	—	Final effluent.	
336	24 „ -	11.50 „	·00	·00	15·5	(60)	13·3	(56)	19·4	(67)	11·1	(52)	—	—	„ „	
337	25 „ -	11.45 „	·00	·00	20·	(68)	20·	(68)	20·5	(69)	8·3	(47)	—	—	Screened and crude sewage.	§ By "general" effluent is meant a mixture of two or more finally treated effluents on leaving the farm.
338	25 „ -	12.30 p.m.	·00	·00	21·1	(70)	13·3	(66)	20·5	(59)	8·3	(47)	—	—	Final effluent.	
339	25 „ -	12.35 „	·00	·00	21·1	(70)	12 7	(55)	20·5	(69)	8·3	(47)	—	—	„ „	

340	25 September	4.15 p.m.	·00	·00	16·6 (62)	12·7 (55)	20·5 (69)	8·3 (47)	—	—	General effluent.	
341	26 ,, -	11.30 a.m.	·00	·00	18·8 (66)	13·3 (56)	21·1 (70)	8·3 (47)	—	—	,, ,,	
342	26 ,, -	11.35 ,,	·00	·00	18·8 (66)	20· (68)	21·1 (70)	8·3 (47)	—	—	Screened and crude sewage.	
343	26 ,, -	11.45 ,,	00	·00	18·8 (66)	13·3 (56)	21·1 (70)	8·3 (47)	—	—	Final effluent	
344	26 ,, -	11.50 ,,	·00	·00	18·8 (66)	12·7 (55)	21·1 (70)	8·3 (47)	—	—	,, ,,	
345	26 ,, -	3 p.m.	·00	·00	21· (70)	20·5 (69)	21·1 (70)	8·3 (47)	—	—	Screened and crude sewage	
346	27 ,, -	11.30 a.m.	·00	00	16·6 (62)	13·3 (56)	—	—	—	—	General effluent.	
347	27 ,, -	11.45 ,,	·00	00	16·6 (62)	13·3 (56)	—	—	—	—	Final effluent.	
348	27 ,, -	11.50 ,,	·00	·00	16·6 (62)	12·7 (55)	—	—	—	—	,, ,	
	1902:											
436	4 February -	Noon Mon to. 11 a.m. Tues.	·15 s.v.	·00	—	—	—	—	—	—	Screened and crude sewage.	24 hours samples.
467	5 ,, -	Noon Tues. to 11 a.m. Wed.	·00	·00	—	—	—	—	—	—	,, ,, ,,	24 hours samples.
468	6 ,, -	Noon Wed. to 11 a.m. Thurs.	·00	·00	—	—	—	—	—	—	,, ,, ,,	24 hours samples.

NOTTINGHAM SEWAGE FARM—*continued.*

TABLE II.

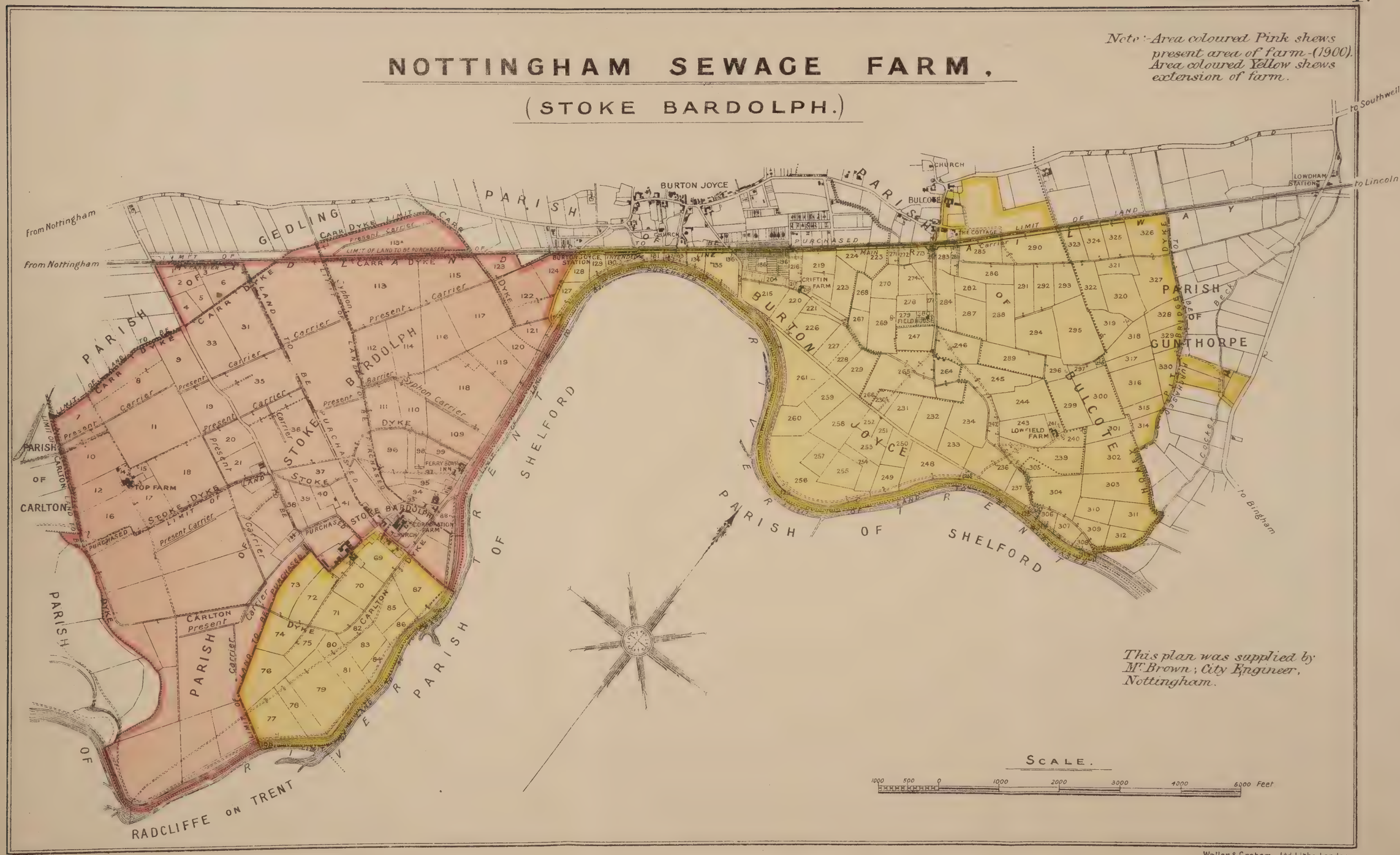
Effluents.

Number of Sample.	Number of times the Sewage has passed through the Soil.	Area of plot or plots Sewaged at the time of drawing Sample.	Length of time these plots had been Sewaged previously to drawing Sample.	Nature of Crops grown on Plots.	REMARKS.
		Acres.			
11	Once - -	*15·5	12 days; day and night sewage.	Fallow -	*This plot was sewaged continuously by night only since Oct. 10th up to Nov. 23rd and since then received both day and night sewage.
12	,, - -	(a) 13· (b) 10·5 (c) 11·25	(a) 7 days; night sewage only. (b) 15 days; night sewage only. (c) 15 days; night sewage only.	,, -	Plots sewaged for 12 hours by night.
14	,, - -	15·5	7 days - - -	,, -	After Dec. 5th this plot only received night sewage, resting during the day.
15	,, - -	(a) 13· (b) 10·5 (c) 11·25	(a) 14 days; night sewage only. (b) 22 days; night sewage only. (c) 22 days; night sewage only.	,, -	Plots sewaged for 12 hours by night only.
16	,, - -	12·	42 days; day sewage only.	,, -	Plots sewaged for 12 hours by day only.
17	,, - -	(a) 13· (b) 10·5 (c) 11·25	(a) 21 days; night sewage only. (b) 29 days; night sewage only. (c) 29 days; night sewage only.	,,	
18	,, - -	(a) 13· (b) 10·5 (c) 11·25	(a) 22 days; night sewage only. (b) 30 days; night sewage only. (c) 30 days; night sewage only.	,,	
19	,, - -	12·	5 days; day sewage only.	,, -	Plot had three days rest.
20	,, - -	15·5	17 days; night sewage only.	,,	
110	,, - -	12·	1 day - - -	Mangolds -	Plot sewaged with day sewage for 12 hours
111	,, - -	12·	2 days - - -	,,	,, ,, ,, ,, ,,
113	,, -	12·	3 ,, - - -	,,	,, ,, ,, ,, ,,
115	,, - -	11·25	14 ,, - - -	Cabbage -	,, ,, ,, ,, ,,
116	,, - -	11·25	15 ,, - - -	,,	,, ,, ,, ,, ,,
118	,, - -	15·5	16 ,, - - -	Kohl Rabbi	Plot sewaged with night sewage for 12 hours
119	,, - -	11·25	16 ,, - - -	Cabbage -	Plot sewaged with day sewage for 12 hours
121	,, - -	—	—	—	General effluent.
330	,, - -	11·25	†5 ,, - - -	Cabbage -	†Plots receiving sewage for 12 hours by day only.
331	,, - -	13·	†4 ,, - - -	Mangolds.	
332	,, - -	—	—	—	General effluents.
333	,, - -	—	—	—	
335	,, - -	11·25	†6 ,, - - -	Cabbage.	
336	,, - -	13·	†5 ,, - - -	Mangolds.	
338	,, - -	11·25	†7 ,, - - -	Cabbage.	
339	,, - -	13·	†6 ,, - - -	Mangolds.	
340	,, - -	—	—	—	General effluents.
341	,, - -	—	—	—	
343	,, - -	11·25	†8 ,, - - -	Cabbage.	
344	,, - -	13·	†7 ,, - - -	Mangolds.	
346	,, - -	—	—	—	General effluent.
347	,, - -	11·25	†9 ,, - - -	Cabbage.	
348	,, - -	13·	†8 ,, - - -	Mangolds.	

NOTTINGHAM SEWAGE FARM.

(STOKE BARDOLPH.)

Note:-Area coloured Pink shews present area of farm-(1900). Area coloured Yellow shews extension of farm.



This plan was supplied by Mr. Brown; City Engineer, Nottingham.

SCALE.

1000 500 0 1000 2000 3000 4000 6000 Feet

3311. 9. 02

Weller & Graham Ltd Litho London.

NOTTINGHAM SEWAGE FARM.

Scale :- Six Inches to one Mile

RIVER SAMPLES.

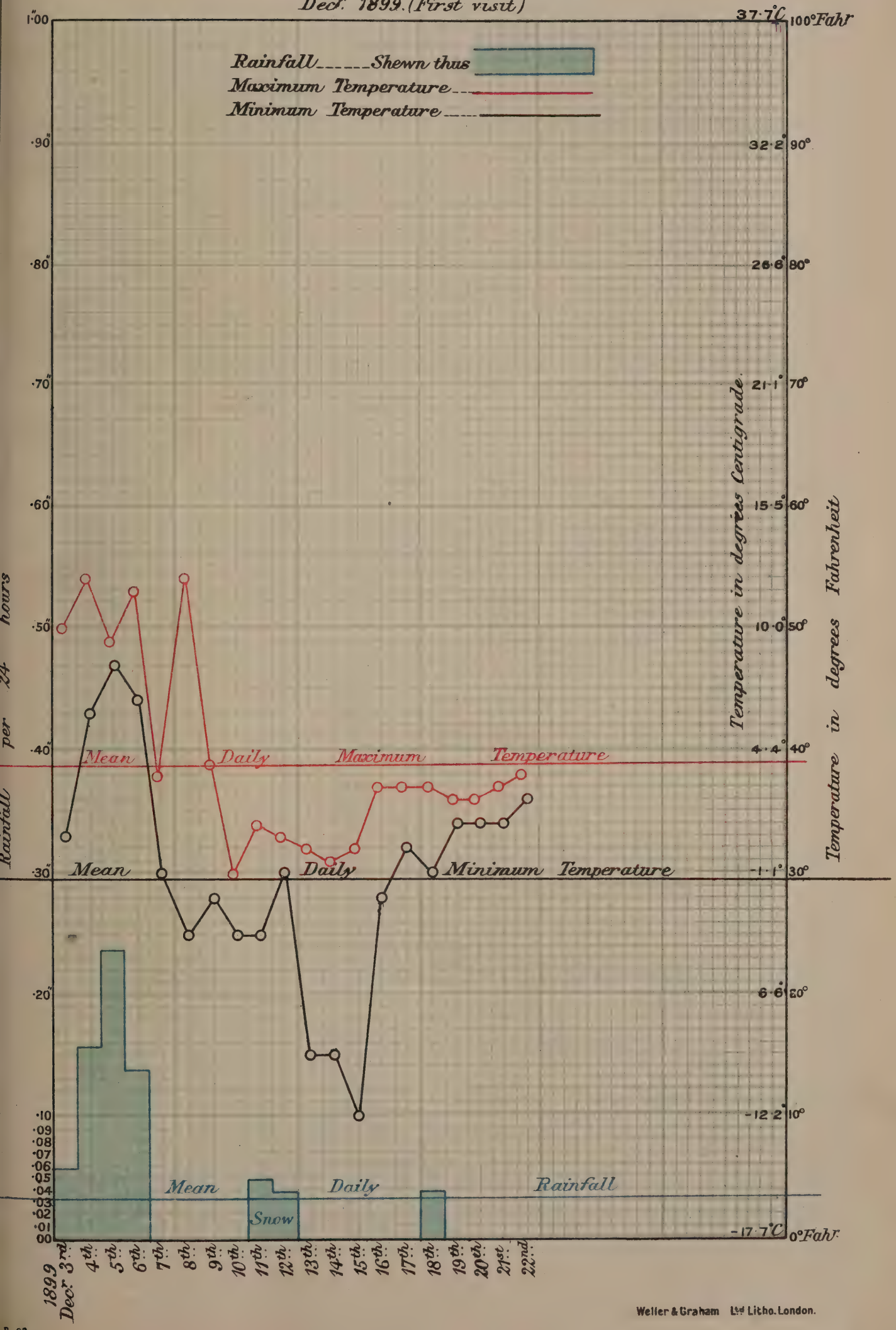
SECTION OF SOIL IN CUTTING FOR NEW STEEL SYPHON.

3311 7.1902.

Weller & Graham Ltd Litho. London.

NOTTINGHAM SEWAGE FARM.

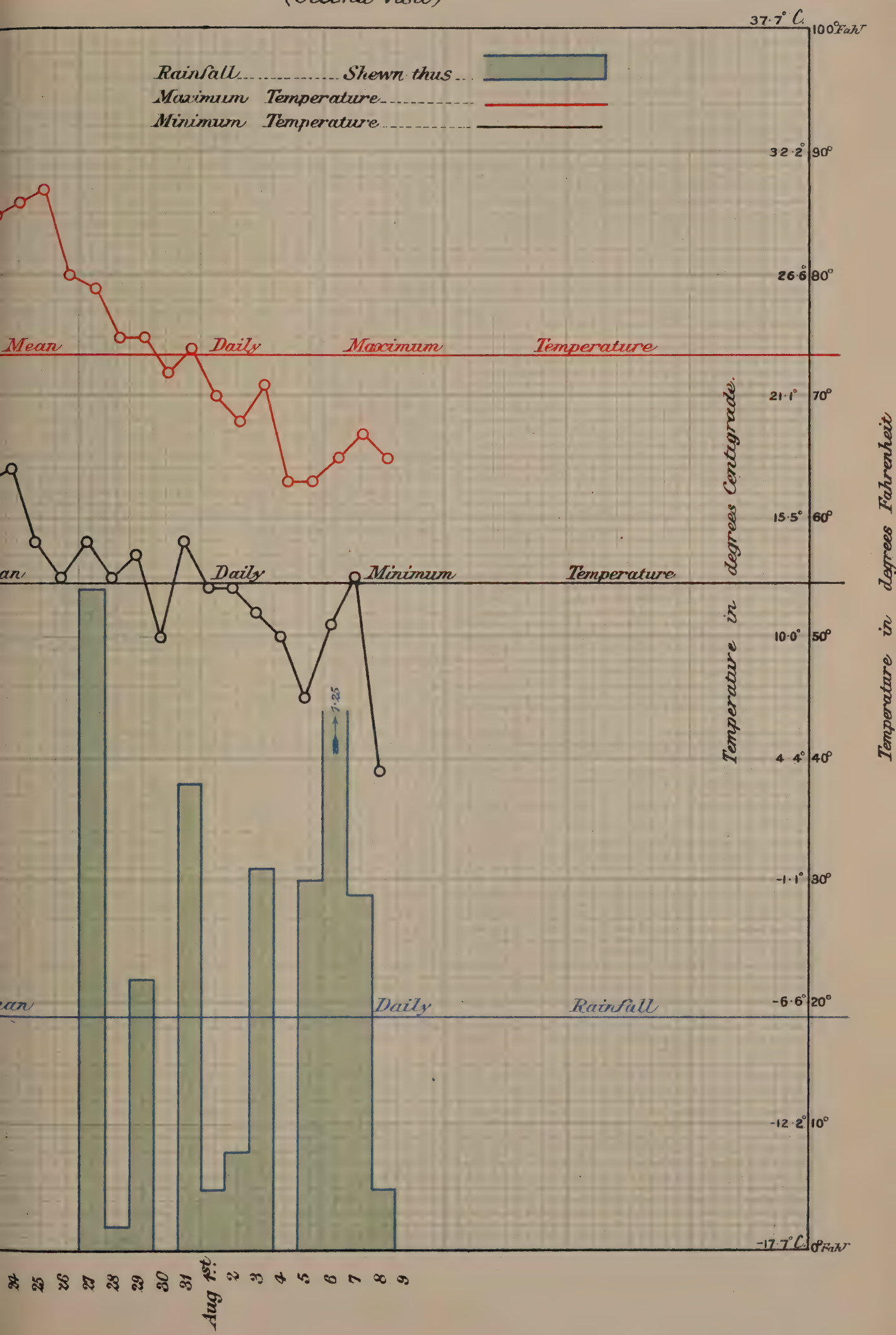
Decr. 1899. (First visit)



Weller & Graham Ltd Litho. London.

NOTTINGHAM SEWAGE FARM.

(Second Visit)



E. Weller & Grahams, Ltd Lithp. London.

NOTTINGHAM SEWAGE FARM—*continued.*

TABLE III.

* Comparative Effluent Samples : or Samples taken from the same plots of land.

December, 1899.	July, 1900.	September, 1901.	REMARKS.
Sample No. 11 - -	Sample No. 110 - -	Sample No. 330 - -	*By "Comparative" Samples is meant samples drawn from the same areas of land, and the effluents in brackets are comparable with each other so far as the area of land sewaged is concerned.
,, ,, 14 - -	,, ,, 111 - -	,, ,, 335 - -	
,, ,, 20 -	,, ,, 113 - -	,, ,, 338 - -	
		,, ,, 343 - -	
		,, ,, 347 - -	
,, ,, 12 - -	,, ,, 115 - -		
,, ,, 15 - -	,, ,, 116 - -		
,, ,, 17 - -	,, ,, 119 - -	,, ,, 331 - -	
,, ,, 18 - -		,, ,, 336 - -	
		,, ,, 339 - -	
		,, ,, 344 - -	
,, ,, 10 - -		,, ,, 348 - -	
,, ,, 19 - -			

TABLE IV.

Sewage Samples.

Number of Sample.	Nature of Sewage.	Time taken.	REMARKS.
10	Strong, dark colour - - -	12 (noon) - -	Part of the sewage gravitates to the farm and part is pumped ; only the sewage pumped is screened.
13	,, dye refuse - - -	12.15 p.m. - -	Screened and crude sewage.
109	,, ,, ,, - - -	12.55 a.m. - -	,, ,, ,,
114	,, ,, ,, - - -	12.15 p.m. - -	,, ,, ,,
329	Fairly strong, dye refuse - -	1.50 p.m. - -	,, ,, ,,
334	Strong, deep brown colour -	11.35 ,, - -	,, ,, ,,
337	,, ,, ,, -	11.45 ,, - -	,, ,, ,,
342	,, ,, ,, -	11.35 ,, - -	,, ,, ,,
345	Strong - - - -	3 ,, - -	,, ,, ,,

RUGBY (High Level) SEWAGE FARM.

(Rugby Urban District Council.)

1. Situation of farm—New Bilton about 1 mile from Rugby.
2. Total acreage of farm—40 acres.
3. Total irrigable area—35 acres.
4. Average area irrigated at one time—7 acres.
5. Population draining to farm—6,000.
6. Population per acre irrigated—171.
7. Gallons of sewage per head per day—50.
8. Dry weather flow of sewage per 24 hours—300,000 gallons.
9. Gallons of sewage (exclusive of storm-water) treated per acre per 24 hours—42,800 = $(\frac{300,000}{7})$.
10. Gallons of sewage treated per acre per 24 hours, on the assumption that each acre of irrigable area is under sewage all the time. (This for purposes of comparison)—$(\frac{300,000}{35})$ = 8,500 gallons.
11. Characters of the sewage—Mainly domestic.
12. Method of treatment—Screening, chemical precipitation, and settling tanks, with surface irrigation and filtration combined, but the former predominating.
13. General characters of the soil and subsoil—Heavy loam, overlying stiff clay.
14. Separate or combined sewerage system—Partially separate
15. The final effluent is discharged into—River Avon.
16. Number of years farm in operation before 1900—33 years.

RUGBY (High Level) SEWAGE FARM REPORT.

SUMMARY OF CONTENTS.

DESCRIPTION OF FARM.

Addendum A.—Notes on Samples.

Additional Notes on Samples.

Table I.—Shewing all samples drawn at the Rugby (High Level) Sewage Farm, together with time of drawing, rainfall, temperatures, description of samples, etc.

Table II.—Giving area of plots from which effluents were drawn, and the time those plots had been under sewage, etc.

Table III.—Sewage samples.

Addendum B.—Plans and diagrams referred to in report.

I.—Plan of farm.

II.—Plan referring to river samples, and plan and section of well on farm.

III.—Temperature and rainfall chart—(1st visit).

IV.—Temperature, rainfall and humidity chart—(2nd visit).

RUGBY HIGH LEVEL SEWAGE FARM.
(Rugby Urban District Council.)

(Domestic Sewage.)

The sewage, which is domestic, with the exception of some oil from Willans and Robinson's Engine Works, is treated chemically in precipitation tanks, and afterwards on land by surface irrigation and filtration.*

The farm is situated on the Upper Lias formation. The surface soil has a depth of about 10 in. heavy loam overlying yellow clay, which forms a belt about 5ft. to 6ft. deep above the lias. Some of the land cracks beneath the surface in hot weather. Potholes of gravel occur in places.

The farm has been used for sewage disposal for 33 years, and for the first eight years dealt with the whole of the sewage of Rugby. It is managed by the Urban District Council, who, however, let it to a tenant farmer. The Council have the absolute direction and control of the sewage works, and also of the application and disposition of the sewage on the farm.

The average dry weather flow per 24 hours is about 300,000 gallons, or 50 gallons per head.

The districts now draining to this farm are the N.W. and S.W. parts of Rugby, and the population is 6,000. The rest of the Rugby sewage is treated on another farm.

The water supply is 26·5 gallons per head, and is obtained part from the River Avon and part from gathering grounds and wells at Moreton and Bilton.

The town is entirely on the w.c. system. All the streets are macadam.

The separate system is used in parts of the town, but all the water from the back portions of roofs and yards drains to the foul water sewers. The average annual rainfall at Rugby from 1855 to 1897 was 25·62 in. For the year 1900 the rainfall was 30·68 in.†

The whole of the sewage gravitates to the farm. Formerly a portion of it was pumped. The sewers, on the whole, are in a fair condition; a large amount of subsoil water, however, is admitted to some of the older sewers, where clay joints have been used instead of cement. The gradients are generally self-cleansing; where necessary the sewers are flushed by hose, and flushing penstocks in the manholes.

A portion of the sewage is brought to one set of settling tanks by a 36 in. circular brick culvert with a gradient of 1 in 718; and the remainder by a 12 in. syphon 1,000 yards long to the settling tanks on the farm. The average time the sewage takes to reach the tanks from the town is about 1½ hours. It will be convenient to refer to the first-named tanks hereafter as the "low level" and the latter as the "high level" tanks. About one-half of the total sewage now is treated at each set of tanks.

There is one storm overflow situated in the allotment gardens above Messrs. Willans and Robinson's works, but it did not come into operation at the time of the visits to the farm, and is not recorded to have come into use within recent years. Whatever sewage the 12in. syphon will not take passes by an 18in. pipe to the low level tanks, and thence all goes on to the farm. The low level tanks are in duplicate 87ft. 6in. long by 25ft. by 3ft. 6in. deep (average depth) with a combined capacity of about 95,000 gallons; both are usually worked together on the continuous system, and are cleaned out about once a fortnight, the sludge being drawn off by chain pumps into sludge bays adjoining the tanks; about 12 tons of wet sludge per week are produced.

* With regard to the proportion treated by surface irrigation and filtration respectively, it is impossible to give anything other than an approximate idea, as the conditions affecting each are constantly changing. Broadly speaking, in the case of Rugby, when a field has been sewaged for two or three days, considerably more sewage is treated on the surface than by filtration, as any cracks which may be present gradually tend to fill up. The relation between the amount of sewage treated by filtration and surface irrigation depends in great measure upon the degree of moisture present in the soil. If after a heavy shower sewage is put on a fresh piece of ground it will reach the bottom of the plot much faster than if the soil were dry.

† I am indebted to Mr. George M. Seabroke, of Rugby, for the data regarding the Rugby rainfall.—G. B. K.

The sewage at the time of the first visit to the farm was treated before entering the tanks with alumino ferric, lime and sulphate of iron, alumino ferric alone being used at night. About 144 gallons each of lime and sulphate of iron solutions were used during the 12 hours, and two blocks of alumino ferric, or about 1 cwt. per 24 hours. The lime and copperas were run into the sewage from tubs, and the amounts varied considerably. The alumino ferric was suspended in an iron cage in the sewage channel, above the junction of that channel with the tanks.

The chemically treated sewage, in flowing through the tanks, passes through two wooden screens perforated with ⅞in. holes placed 3in. apart each way, and thence on to the farm, the outfall coming out about half way down the farm, 10 acres of land being available for the low level sewage. A large quantity of oil from Messrs. Willans and Robinson's Engine Works close by occasionally comes into these tanks, and was found very injurious to the rye-grass on the farm. It is now skimmed off twice a day from the surface of the tanks, and is not utilised in any way. The high level tanks are also in duplicate, 65ft. long by 15ft. by 2ft. (average depth) and having a capacity of about 12,000 gallons each.* These tanks are used on the continuous system, one at a time for a normal flow, but both for a storm, and are cleaned out once a week. The settlement effected by these tanks is very small. The same chemicals were used at these tanks as at the low level; the sewage, however, at these tanks passes through an iron bar screen (¾in. spaces) at the foot of each tank. Chemical treatment was suspended for a time shortly after the first visit to the farm, only being used during the hot weather to lessen smell.

The high level tanks are very old and are in disrepair. The sides and bottom of the tanks are formed of brick on edge; many of these bricks have become displaced, rendering the efficient cleaning out of the tanks impossible. About 6 tons of wet sludge are produced per week at the low level tanks. After the greater part of the sludge has been run off from the tanks into sludge bays placed at a lower level, they are cleaned out by hand scoops. The sludge is used by the tenant as a top dressing for grass land away from the sewage farm. The Rugby School baths, holding about 53,000 gallons of water, discharge into a sewer leading to these tanks, and when flushed out cause a large rush of water through the tanks, stirring up the sludge.

The settled sewage, on leaving the tanks, is distributed over the farm by earthen carriers. These carriers are very faulty, being nothing more than rough open ditches; the sluices are also in disrepair. These carriers are cleaned out two or three times a year, and the effect of this cleansing is on each occasion to deepen then. The deepening often causes portions of the sides to fall in and this results in the retention in the carriers of solids in the sewage, which remain there and putrefy.

Crude sewage is occasionally applied to one field across the L. and N. W. Railway. There is not a large amount of subsoil water on the farm now. Formerly there was a large quantity in the potholes of gravel previously mentioned; drains have now been laid to these, and the water has a free outflow.

The total area of the farm is (1900) 40 acres, of which 35 acres are irrigable, 10 being available for the low level, and 25 for the high level sewage. This area (35 acres) deals with (excluding storm water) a sewage flow of 300,000 gallons per 24 hours from a population of 6,000 persons, which is equal to 171·4 persons per irrigable acre, or about 8,570 gallons per acre. Under normal conditions about seven acres are sewaged at once, which is equivalent to 42,850 gallons of sewage treated per acre per 24 hours. The sewage flow at the farm is greatest and strongest from about 8 a.m. to noon. The farm is under-drained with 2 in. socketted tiles laid herring-bone fashion, one chain apart, at an average depth of 3 ft. 9 in. and connected to 4 in. and 6 in. butt main

* It should be borne in mind that the time the sewage stays in the tanks depends entirely upon the rate of flow of the sewage, and that as a rule in dry weather when the sewage is strongest, the time for settlement is least. The quantity of sludge present in the tank also influences the amount of sedimentation which takes place, as it reduces the tank capacity.

drains. There are, in addition, some old land drains, which were in existence before the farm was used for sewage, laid at a depth of about 18 in. Some of these have since been blocked up.

The filling above the drains varies considerably; usually, turf was laid on the top of the drain, and the soil excavated replaced; a few of the drains come out on the surface of the farm, but the majority discharge by an under-drainage outfall into the River Avon, which runs along the bottom of the farm.

The irrigable area is not liable to floods.

The farm has a rather steep slope towards the river, and this allows of the high level sewage being treated once, twice, or three times. After the high level sewage has been treated once or twice, it mixes with the low level sewage, which comes out about half way down the farm, and is treated with it. (Add. B. 1.). The high level sewage is thus treated, as a rule, three times, and the low level once.

The sewage is run on to the same area of land continuously day and night for periods varying from three to seven days, according to circumstances. A slight shower of rain when the ground is saturated causes very rapid fluctuations in the amount of sewage arriving at the farm, and owing to corn crops being grown, which cannot always be irrigated, there is not sufficient area of land to deal with these sudden increments effectually.

The crops grown on the farm are rye-grass, mangolds, cabbages, oats and wheat, and they are disposed of by the tenant. For some five years after the start of the farm, whilst in the hands of the Urban District Council, the crops were disposed of by auction. The annual cost of treating the sewage is about £200; including interest on loan, it is £225. Receipts—apportioned rent about £63, equal to about £1·48 per 1,000,000 gallons exclusive of storm water.

There are two main effluent outfalls to the River Avon, consisting of an effluent intercepting ditch running along the foot of the farm, and provided with two stoneware pipe outlets to the river. Moles cause considerable trouble by boring holes down to the under-drains in dry weather, and rats damage the carriers, causing the sides to fall in. The River Avon, into which the effluent flows, appears to be in good condition, and there was no sign of any nuisance from the farm. The volume on one occasion during very dry weather (July, 1900) was at the rate of 6,000,000 gallons per 24 hours. In wet weather (March, 1900) the flow was at the rate of 15,000,000 gallons per 24 hours. The volume of effluent to river water normally is about as 1 to 30.

The chief difficulties in working the farm are the want of land for moving the sewage, as the wheat and oats cannot be sewaged, and occupy valuable space.

In hot, close weather, considerable nuisance arises from the cleaning out of the tanks, and also from the carriers. The latter is caused by matter derived from the sewage being held back by the inequalities in the carriers and putrefying.

Notes on Temperature, Rainfall, Etc.

During the summer visit to Rugby (June 18th to July 8th, 1900) the mean daily maximum temperature averaged 19·6°C. (67.4°F.) the highest maximum reading being 23·8° C. (75° F.) and the lowest 12·2° C. (54° F.)

The mean daily minimum was 8·3° C. (47° F.). the highest and lowest readings being 14·4° C. (58° F.) and 5·5° C. (42° F.) Rain fell on 11 days out of 21, heavy falls taking place on June 24th and 25th, when ·40 inch. and ·47 inch. was registered. The mean daily rainfall was ·065 inch.

During the second visit to the farm (February 18th to March 8th, 1901) the mean daily maximum was 8·1° C. (46·7° F.) the highest and lowest maximum readings being 13·3° C. (56° F.) and 3·3° C. (38° F.). The mean daily minimum was 1·4° C. (34·6° F.), the highest and lowest minimum readings registered being 7·7° C. (46° F.) and 6·1° C. (21° F.). The mean daily humidity averaged 86·9 (100—saturation). The mean daily rainfall was ·056 inch., rain falling on 15 days out of 24. The greatest rainfall took place on March 3rd, when ·30 inch. fell. Snow occurred on February 18th. (*See* Add. B. III. & IV.)

RUGBY HIGH LEVEL SEWAGE FARM.

(Additional Notes on Samples.)

Sample No. 94.—This effluent was from crude sewage which had neither passed through the settling tanks nor been chemically treated.

Effluent had a slight sewage smell. The rye-grass was a fair crop, and ready for cutting (third crop).

Sample No. 96.—This effluent, in common with all other effluents treated twice (unless otherwise mentioned), after passing over the first field, mixes with the precipitated sewage from the low level tanks, further down the farm, and this mixture is then passed over another plot before reaching the river.

Sample No. 98.—Effluent off rye-grass after three days' rest, *i.e.*, off the same plot as No. 94, and therefore comparable with it, for the purpose of ascertaining the effects of rest.

Sample No. 99A.—This effluent was obtained from oats which had previously been cut to make ensilage.

Sample No. 100.—Very slight sewage smell.

Sample No. 105*.—River Avon water taken above effluent outfalls. River very low, apparently in good condition. Bed of river clean. (Add B. II.)

Sample No. 107.—River water and effluent taken after mixing, 80 yards below No. 106.

Sample No. 108.—River water and effluent taken 250 yards below sample No. 107.

Sample No. 226B.—River water and effluent taken 200 yards below effluent outfalls, clear green colour. River high.

Sample No. 227.—Water drawn from well at manager's house on farm, well 20ft. deep, 10ft. of water. Well sunk into the Lias Clay. (Add B. II).

Water clear and effervescing. The sample was drawn from the pump after three minutes' pumping.

Sample No. 230A.—River water above effluent outfalls, rather cloudy, due to flood water coming down. *See* note as to Sampl e No. 105.

Sample No 231.—"Street washings" taken from a surface water drain; not much vehicular traffic in the street, surface of street very clean from previous heavy showers. This sample would include water from the front roofs of houses.

Sample No. 234A.—River water taken 80 yards below effluent outfalls, river very high and in flood, a cloudy sample.

Sample No. 234.—General effluent, faint yellow colour, no smell; effluent on mixing with river water turned a red-brown colour.

Sample No. 238A.—River water and effluent taken 10 yards below effluent outfall, clear, no smell, river still fairly high.

Sample No. 239†.—Well water taken from same source as No. 227.

---

* The low level sewage farm effluent outfall discharges into the river about two miles above the point where this sample was taken.

† The land is sewaged within about 40ft. of this well, and it appears quite probable that the well may have been polluted.

TABLE I.

(Domestic Sewage.)

Number of sample.	Date of drawing sample.	Time of day.	Rainfall day previous to drawing sample.	Rainfall day of drawing sample.	Atmospheric temp. time of drawing sample.	Temperature of sample.	Max. temp. during the 24 hours.	Min. temp. during the 24 hours.	Humidity (9 a.m.)	Dissolved oxygen in sample.	Brief description of sample.	Remarks.
	1900.		Inches.	Inches.	°C. °F.	°C. °F.	°C. °F.	°C. °F.				
93	June 19	11.0 a.m.	·00	·01	20· (68)	13·3 (56)	23·3 (74)	10·5 (51)			Crude sewage - -	
94	,, ,,	1.0 p.m.	,,	,,	21·6 (71)	15· (59)	,, ,,	,, ,,			Final effluent - - -	
95	,, 20	11.15 a.m.	·01	·11	20·5 (69)	15· (59)	20·5 (69)	7·7 (46)			Screened, settled, and precipitated sewage -	
96	,, ,,	12.15 p.m.	,,	,,	20· (68)	21·1 (70)	,, ,,	,, ,,			Final effluent - - -	
97	,, 25	1.45 ,,	·40	·47	20·5 (69)	13·3 (56)	,, ,,	9·4 (49)			Crude sewage - - -	
98	,, ,,	3.15 ,,	,,	,,	14·4 (58)	13·8 (57)	,, ,,	,, ,,			Final effluent - - -	*Mean daily max. temp. 19·6° C. (67·4)° F. Mean daily min. temp. 8·3° C. (47)° F. Mean daily rainfall ·065 in.
99	,, 27	12 (noon)	·00	·00	14·4 (58)	13·3 (56)	,, ,	7·2 (45)			Screened settled, and precipitated sewage -	
99A	,, ,,	1.15 p.m.	,,	,,	17·2 (63)	17·2 (63)	,, ,,	,, ,,			First field effluent - -	
100	,, ,	2.5 ,,	,	,,	15·5 (60)	15· (59)	,, ,,	,, ,,			Second or final effluent -	
101	July 2	10.30 a.m.	,	·06	18·8 (66)	14·4 (58)	22·2 (72)	10· (50)			Screened, settled, and precipitated sewage	*For the period June 18th to July 8th, 1900.
101A	,, ,,	11.30 ,,	,,	,,	20· (68)	18·8 (66)	,, ,,	,, ,,			First field effluent - -	
102	,, ,,	12.15 p.m.	,,	,,	16·1 (61)	17·2 (63)	,, ,,	,, ,,			Second or final effluent -	NOTE.—Samples which may have been affected by rainfall are underlined.
103	,, 3	12.15 ,,	·06	·0	17·7 (64)	17·7 (64)	20·5 (69)	6·6 (44)			Final effluent - - -	
104	,, 4	12.0 ,,	·00	,	,, ,,	17·2 (63)	21·6 (71)	11·1 (52)			,, ,, - - -	
105	,, 9	11.0 a.m.	,,	,,	,, ,,	16·1 (61)					River Avon water - -	§By "general" effluent is meant a mixture of two or more finally treated effluents on leaving the farm.
106	, ,,	11.15 ,,	,,	,,	20· (68)	,, ,,					§General effluent - -	
107	,, ,,	11.30 ,,	,,	,,	17 2 (63)	,, ,,					River water and effluent -	
108	,, ,,	12.0 noon	,,	,	,, ,,	,, ,,					,, ,, ,, ,, -	
	1901.											
224	Feb. 18	4.0 p.m.		·05 †(s)	4·4 (40)	5·5 (42)	6·6 (44)	1·6 (29)	92		Screened and settled sewage - - - -	† (s) signifies snow.
225	,, ,,	5.0 ,,	,,	,,	4·4 (40)	3·3 (38)	,, ,,	,, ,,	,,		General effluent - -	
226	,, 20	12.0 noon	·005 (s)	·00	3·8 (39)	2·2 (36)	3·3 (38)	6·1 (21)	83	c.cs. 1·75	First field effluent - -	

TABLE I—continued :—

(Domestic Sewage.)

Number of sample.	Date of drawing sample.	Time of day.	Rainfall day previous to drawing sample.	Rainfall day of drawing sample.	Atmospheric temp. time of drawing sample.	Temperature of sample.	Max. temp. during the 24 hours.	Min. temp. during the 24 hours.	Humidity (9 a.m.).	Dissolved oxygen in sample	Brief description of sample.	Remarks.
	1901.		Inches.	Inches.	°C. °F.	°C. °F.	°C. °F.	°C. °F.		c.cs.		
226A	February 21	11.15 a.m.	·00	·07	1·6 (35)	2·2 (36)	5· (41)	·5 (33)	89	4·50	General effluent - -	
226B	„ „	11.30 „	„	„	„ „	„ „	„ „	„ „	„	8·	River water and effluent -	
226C	„ 22	11.30 „	·07	·01	5·5 (42)	4·4 (40)	7·7 (46)	3·3 (38)	85	4·	General effluent - -	
227	„ 25	12.0 noon	·00	·00	10· (50)	7·7 (46)	10·5 (51)	3·8 (39)	79	4·25	Well water - - -	
228	„ 26	10.45 a.m.	·00	·13	5·5 (42)	4·4 (40)	6·6 (44)	3·3 (38)	92	·25	First field effluent - -	*Mean daily max. temp. 8·2 °C. (46·75) °F. Mean daily min. temp. 1·4 °C. (34·6) °F. Mean daily humidity 86·9. Mean daily rainfall ·056 in
229	„ „	11.45 „	„	„	„ „	5·5 (42)	„ „	„ „	„	2·5	Final effluent - - -	
230	„ 27	11.40 „	·13	·00	6·6 (44)	„ „	„ „	„ „	„		Final and general effluent	
230A	March 1	11.0 „	·07	·14	8·8 (48)	„ „	10· (50)	·5 (31)	79	6·50	River water - - -	
231	„ 4	10.0 „	·30	·06	6·1 (43)	3·8 (39)	8·8 (48)	7·7 (46)	85		Street washings - -	
	„ 5	12.0 noon	·06	·14	11·1 (52)	8·3 (47)	11·1 (52)	3·3 (38)	73	3·50	Final and general effluent	*For the period Feb. 18th to March 14th, 1901.
233	„ 6	11.15 a.m.	·14	·03	5· (41)	„ „	6·1 (43)	„ „	84		Crude sewage - - -	
234	„ „	12.45 p.m.	„	„	„ „	5·5 (42)	„ „	„ „	„		Final and general effluent	
234A	„ „	12.50 „	„	„	„ „	4·4 (40)	„ „	„ „	„		River water and effluent-	
234B	„ 7	10.45 a m.	·03	·22	„ „	„ „	7·7 (46)	2·7 (37)	92		Final and general effluent	
234C	„ 8	11.15 „	·22	·02	„ „	5·5 (42)	„ „	0·0 (32)	78		„ „	
234D	„ 9	11.50 „	·02	·00	„ „	5· (41)	8·8 (48)	3·8 (25)	84		„ „	
235	„ 11	11.10 „	·00	·00	5·5 (42)	7·7 (46)	11·1 (52)	1·6 (35)	98		Crude sewage - - -	
236	„ „	12.30 p.m.	„	„	6·6 (44)	5·5 (42)	„ „	„ „	„	·00	First field effluent - -	
237	„ „	1.15 „	„	„	7·7 (46)	6·1 (43)	„ „	„ „	„	4·25	Final and general effluent	
238	„ 13	11.20 a.m.	·005	·00	·3 (38)	6·6 (44)	4·4 (40)	1·1 (34)	84	4·	„ „	
238A	„ „	11.30 „	„	„	„ „	6·1 (43)	„ „	„ „	„	6·25	River water and effluent	
238B	„ 14	11.5 „	·00	·00	5· (41)	„ „			92		First field effluent - -	
238C	„ „	11.45 „	„	„	„ „	5·5 (42)			„		Final and general effluent-	
239	„ „	10.0 „	„	„	4·4 (40)	7·7 (46)			„	3·	Well water - - -	
	1902.											
472	February 18	Noon Mon. to 11 a.m. Tuesday.	·00	·00							Screened and settled sewage	24 hours samples.
473	„ 19	Noon Tues. to 11 a.m. Wednesday.	„	„							„ „ „ „	
474	20	Noon Wed. to 11 a.m. Thursday.	„	„							„ „ „ „	

RUGBY HIGH LEVEL SEWAGE FARM

TABLE II.

(Domestic Sewage.)

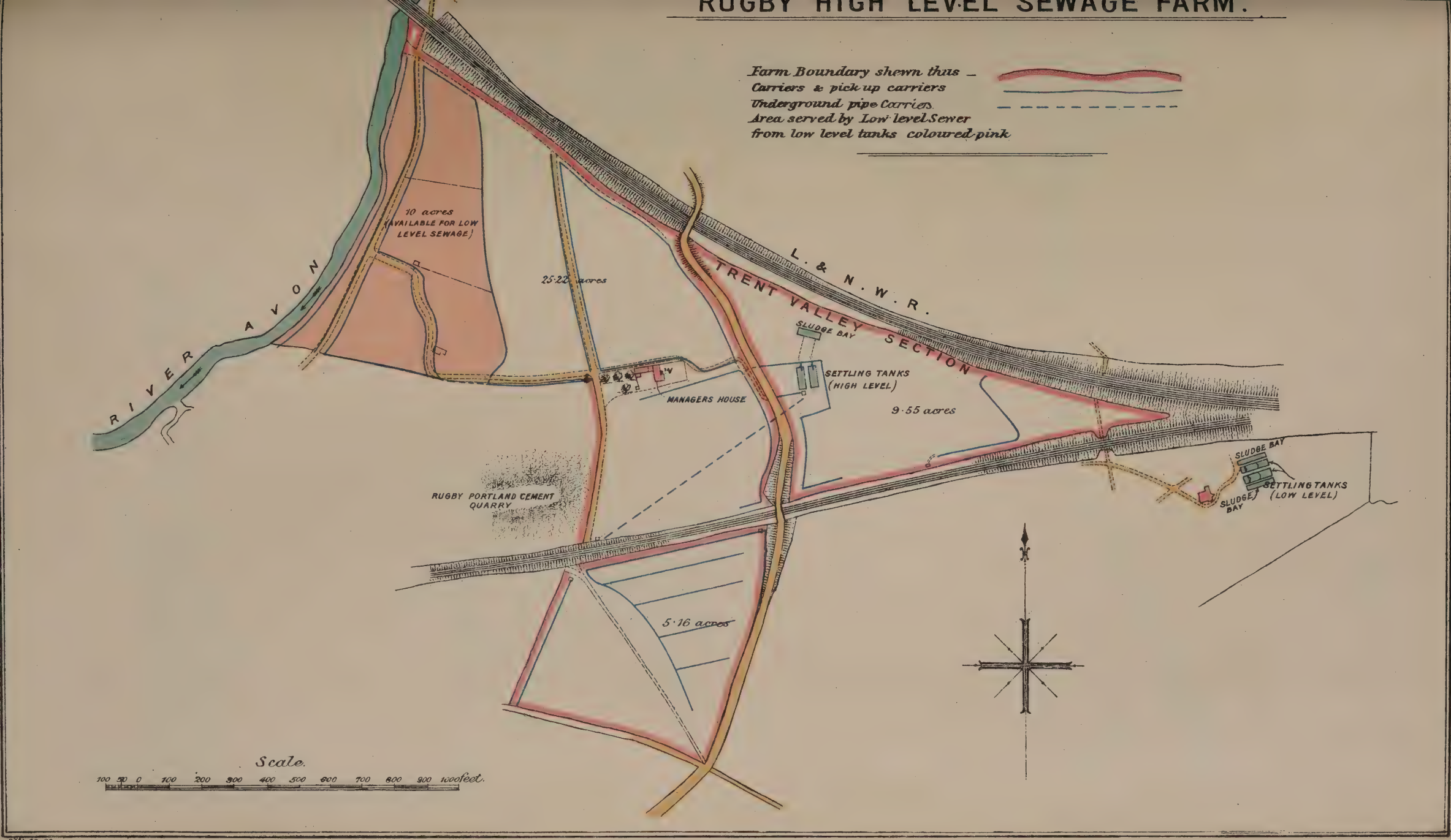
Number of Sample.	Number of times the sewage was passed through or over the soil.	Area of plot or plots sewaged at the time of drawing sample.	Length of time these plots had been sewaged previously to drawing sample.	Nature of crops grown on plots.	Remarks.
		Acres.			
94	once	2·25	10 days	Rye-grass	*Filtration effluent.
96	twice	1·70	5 days	,,	Surface and filtration effluent.
98	once	2·25	6 hours	,,	* ,, ,, ,,
99A	once	1·5	5 days	Young oats (just cut)	* ,, ,, ,,
100	twice	1·5 / ·5	5 days	Rye-grass	* ,, ,, ,,
101A	once	·5	5 hours	Young oats (just cut)	* ,, ,, ,,
102	twice	·75	3 days	Rye-grass	* ,, ,, ,,
103	twice	1· / ·75	1 day / 4 days	Cut oats and rye-grass	* ,, ,, ,,
104	twice	·1 / ·75	2 days / 5 days	Cut oats and rye-grass	* ,, ,, ,,
106	twice				General effluent. NOTE.—All effluents to which an asterisk (*) is prefixed were taken before mixing with the low level sewage.
225	twice	6·		Arable and rye-grass	General effluent (surface and filtration).
226	once	5 75	4 days	Arable	*Filtration ,, ,, ,,
226A	twice			Arable and rye-grass	General ,, ,, ,,
226C	twice			Arable and rye-grass	,, ,, ,, ,,
228	once	4·75	1 day	Arable	*Filtration effluent.
229	twice	4·75 / 1·25	2 days	Arable and rye-grass	,, and surface effluent.
230	twice			Arable and rye-grass	General effluent (surface effluent).
232	twice			Arable and rye-grass	,, ,, ,, ,,
234	twice			Arable and rye-grass	,, ,, ,, ,,
234B	twice			Arable and rye-grass	,, ,, ,, ,,
234C	twice			Arable and rye-grass	,, ,, ,, ,,
234D	twice			Arable and rye-grass	,, ,, ,, ,,
235	twice			Arable and rye-grass	,, ,, ,, ,,
236	once	·75	2 days	Arable	*First ,, ,, ,,
237	twice			,,	General ,, ,, ,,
238	twice	4· / 1·90	2 days	,,	,, ,, ,, ,,
238B	once	4·75	5 days	,,	*First ,, ,, ,,
238C	twice			,,	General ,, ,, ,,

RUGBY SEWAGE FARM.

TABLE III.

(Sewage Samples.)

Number of Sample.	Time sample was taken.	Nature of sewage.	Remarks.
93	11.0 a.m.	Crude sewage - - -	This sewage was applied to the land before being chemically treated, or passed through the settling tanks.
95	11.15 a.m.	Screened and chemically precipitated sewage -	Alumino ferric, sulphate of iron and lime solutions were used—Alumino ferric alone at night.
97	1.45 p.m.	Crude sewage - . -	As No. 93.
99	Noon.	Screened and chemically precipitated sewage -	Chemically precipitated and screened sewage—as No. 95.
101	10.30 a.m.	Screened and chemically precipitated sewage	As No. 97.
224	4.0 p.m.	Screened and settled sewage —dilute - - - -	Not chemically treated. NOTE.—None of the sewage was being chemically treated at this visit.
233	11.15 a.m.	Crude sewage—dilute- -	As No. 93 and 97. An oily film on surface.
235	11.10 a.m.	Crude sewage—strong -	As Nos. 93, 97, and 233. Contained a good deal of sediment.
472 / 473 / 474	24 hours samples.		



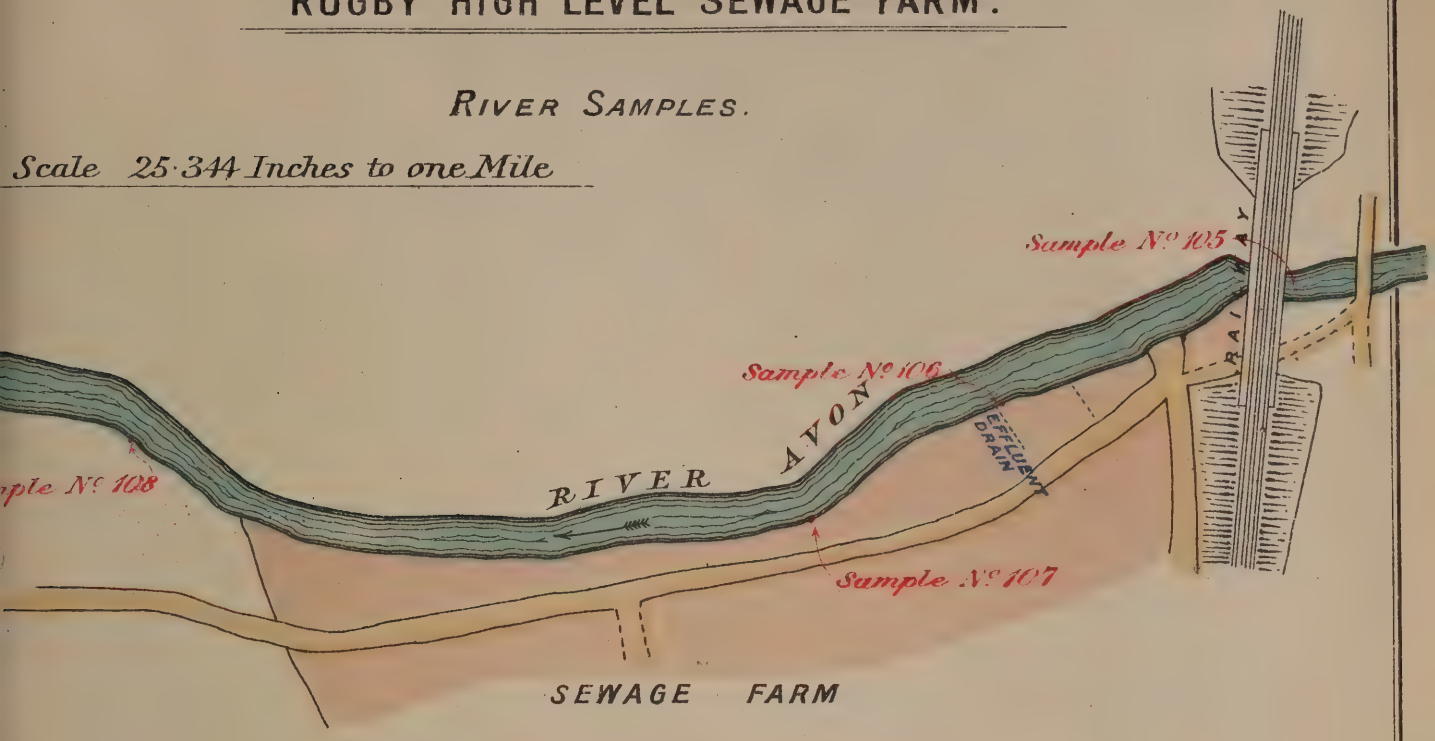
Addendum B.

Weller & Graham Ltd Litho, London.

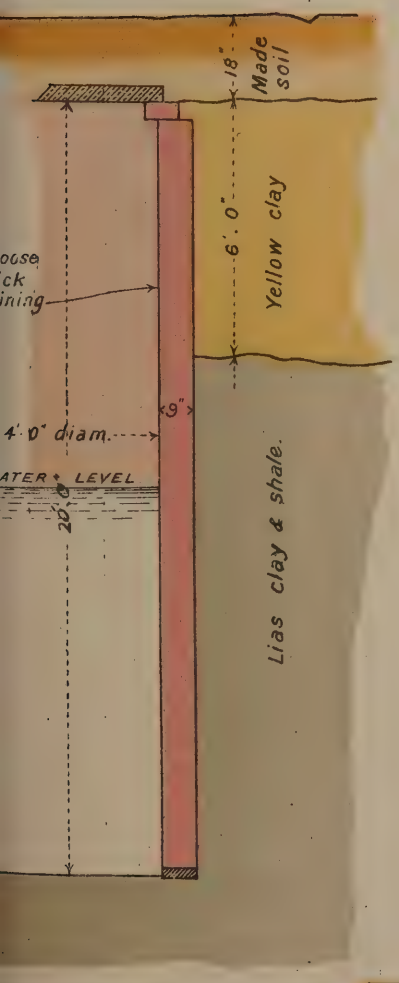
RUGBY HIGH LEVEL SEWAGE FARM.

RIVER SAMPLES.

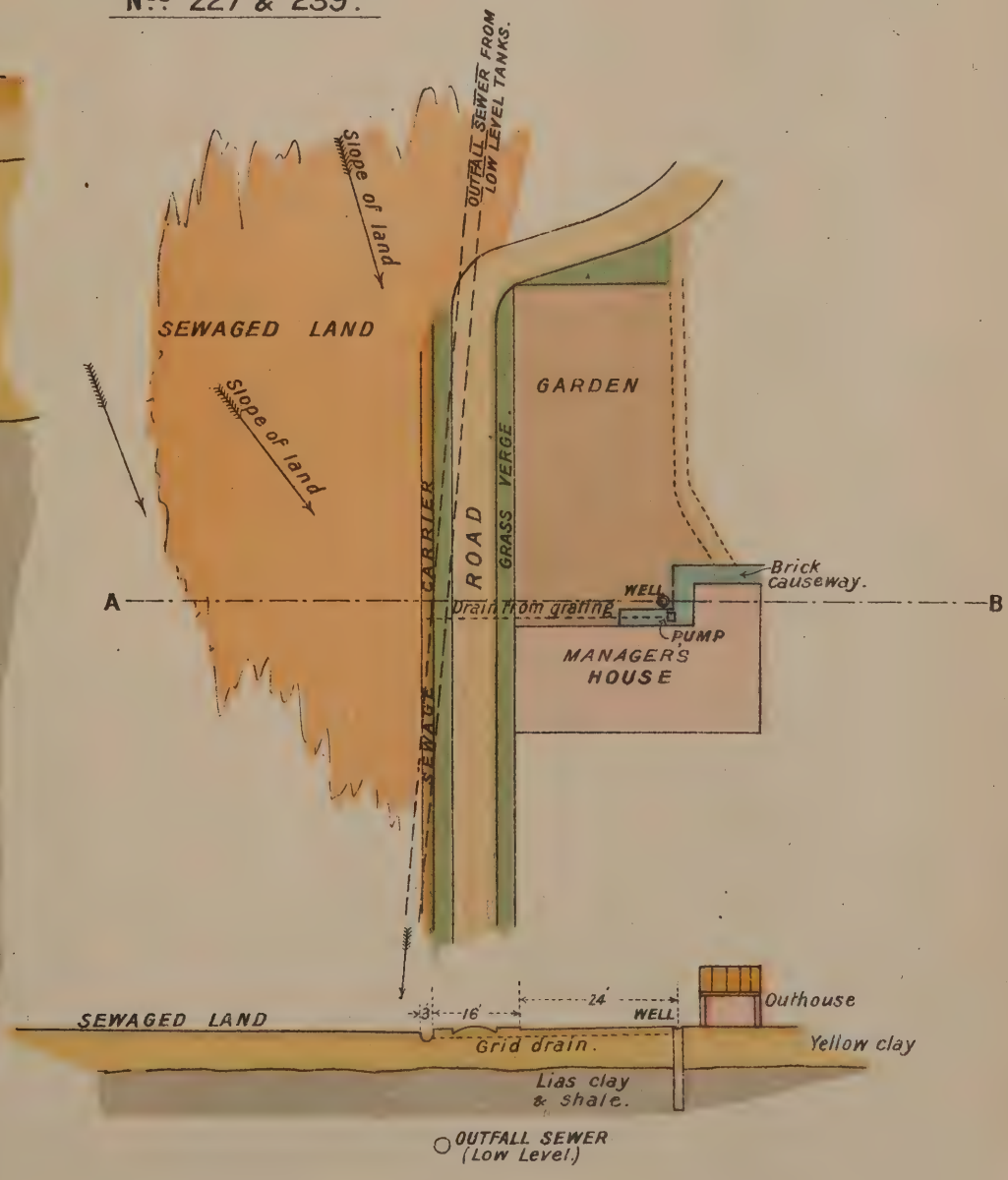
Scale 25·344 Inches to one Mile



SKETCH PLAN & SECTIONS REFERRING TO SAMPLES.
Nos 227 & 239.



PART SECTION OF WELL.

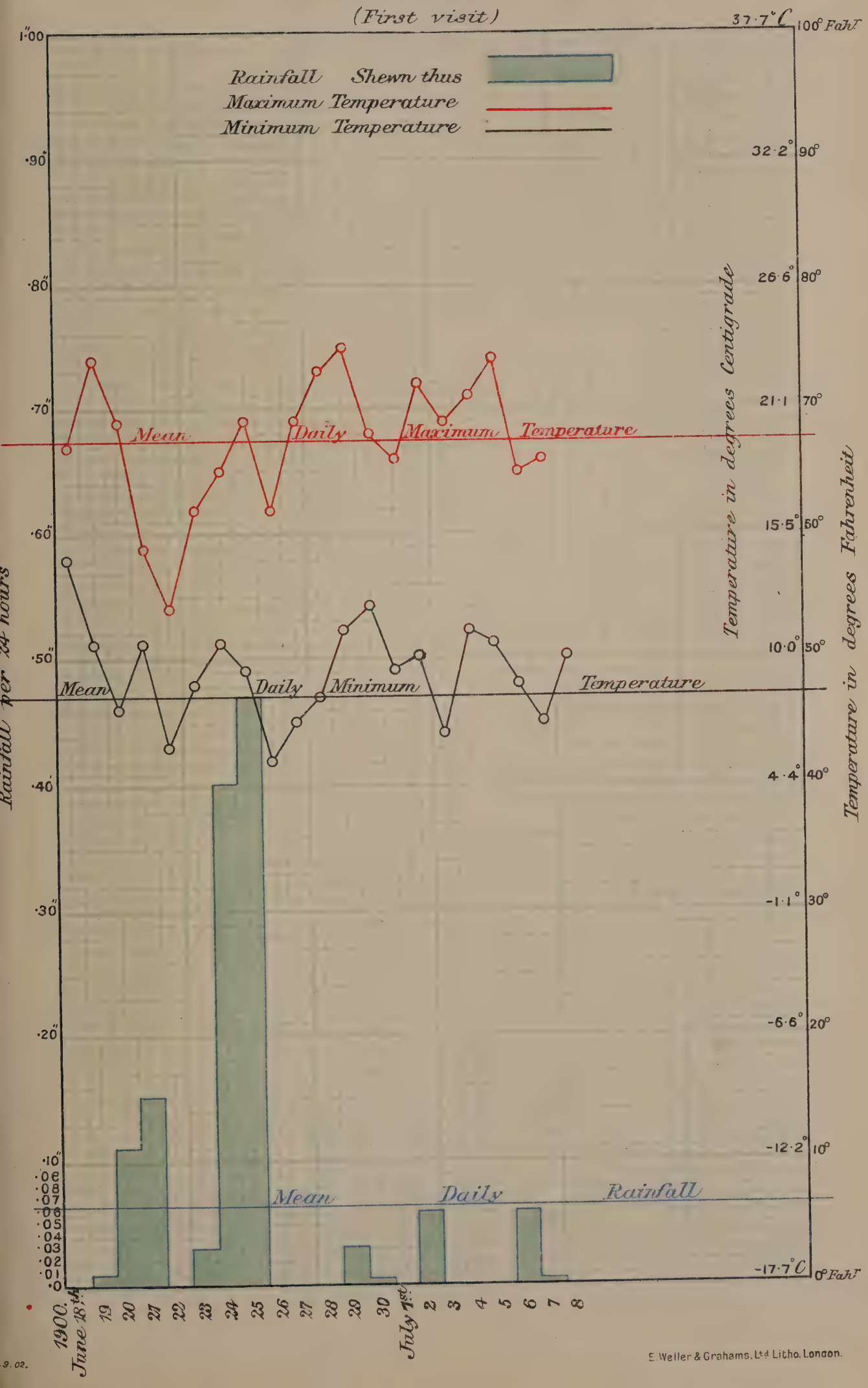


SECTION ON LINE A. B.

Weller & Graham Ltd Litho. London.

RUGBY SEWAGE FARM. (High Level.)

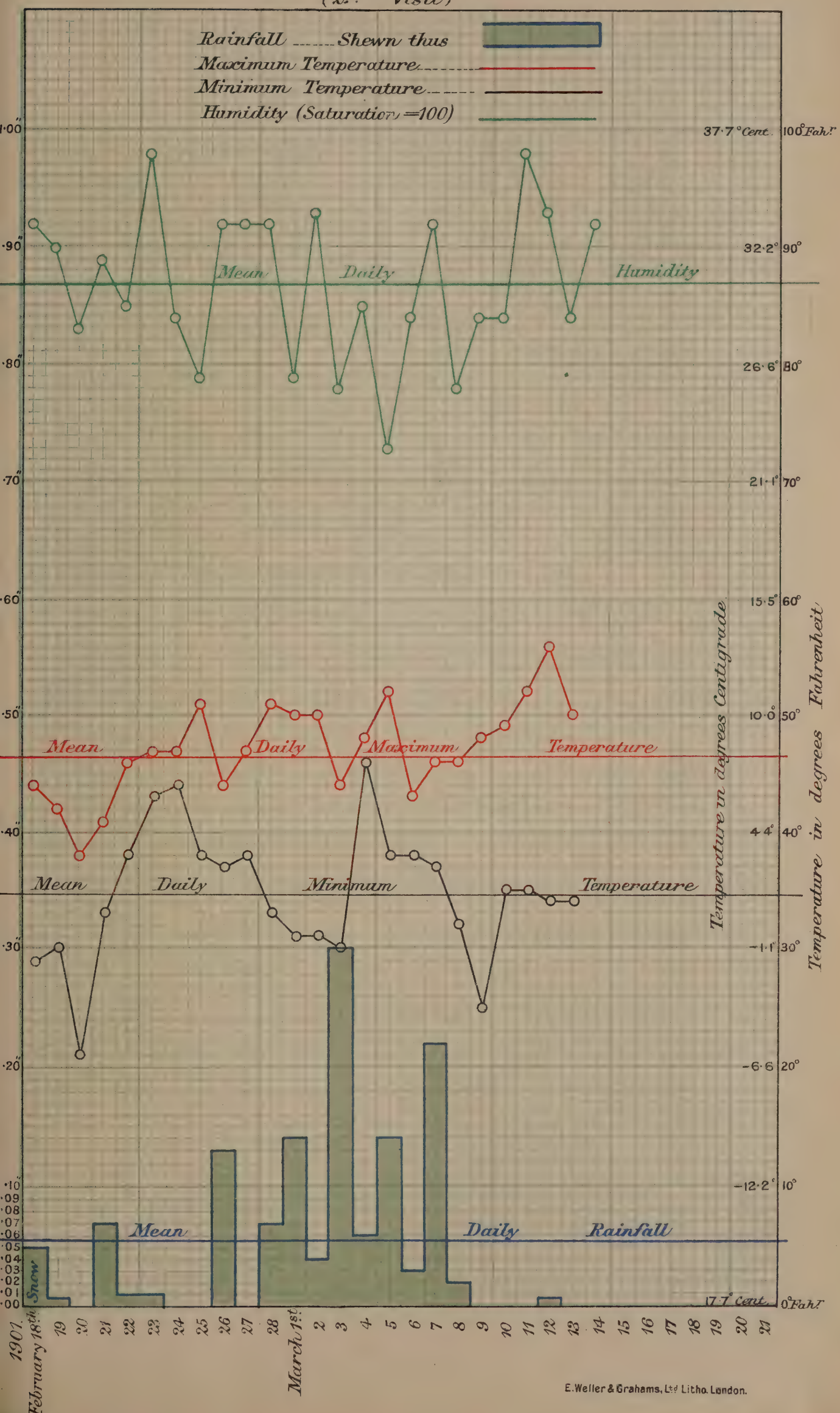
(First visit)



E. Weller & Grahams, Ltd Litho. London.

RUGBY SEWAGE FARM. (High Level)

(2nd Visit)



E. Weller & Grahams, Ltd Litho. London.

SOUTH NORWOOD SEWAGE FARM.

(Croydon Corporation.)

1. Situation of farm.—Closely adjacent to South Norwood.

2. Total acreage of farm.—191 acres.

3. Total irrigable area.—152 acres.

4. Average area irrigated at one time.—50 acres.

5. Population draining to farm.—21,000.

6. Population per acre irrigated.—138.

7. Gallons of sewage per head per day.—285.

8. Dry weather flow of sewage per 24 hours.—600,000 gallons.

9. Gallons of sewage (exclusive of storm water) treated per acre per 24 hours.—12,000 = $(\frac{600,000}{50})$.

10. Gallons of sewage treated per acre per 24 hours, on the assumption that each acre of irrigable area is under sewage all the time. (This for purposes of comparison)—$(\frac{600,000}{152})$ = 4,000 gallons.

11. Characters of the sewage.—Purely domestic.

12. Method of treatment.—Screening, Settling tanks, and Surface irrigation.

13. General characters of the soil and subsoil.—A clay soil resting on London clay.

14. Separate or combined sewerage system.—Partially separate.

15. The final effluent is discharged into.—Chaffinch Beck.

16. Number of years farm in operation before 1900—36 years.

SOUTH NORWOOD SEWAGE FARM REPORT.

SUMMARY OF CONTENTS.

Description of Farm.

Addendum A—Notes on Samples.

Table I.—Shewing all samples drawn at the South Norwood Sewage Farm, together with the time of drawing, rainfall, temperatures, description of samples, etc.

Table II.—Giving area of plots from which samples were drawn and the time those plots had been sewaged, etc.

Additional Notes on Samples.

Table III.—Comparative samples.

Table IV.—Sewage samples.

Addendum B—Plans and diagrams referred to in Report.

I.—Plan of farm.

II.—Plan referring to brook water samples, settling tanks, and section of soil and subsoil.

III.—Temperature and rainfall chart (1st visit).

IV.—Temperature and rainfall chart (2nd visit).

V.—Temperature and rainfall chart (experiment.)

VI.—Diagram shewing number of gallons treated per acre during the experiment.

SOUTH NORWOOD SEWAGE FARM.

(Croydon Corporation.)

(Domestic Sewage).

The sewage is entirely domestic and is treated (1900) by means of screening, settling tanks and surface irrigation.

The surface soil varies from 6in. to 10in in. depth, and over the greater portion of the farm it is a stiff heavy soil; some lighter soil occurs in parts. (Add. B. II.) In comparison with the Leicester farm, the soil is not so stiff, partaking more of the nature of a brick earth. The entire farm overlies a subsoil of the London clay. Sewaging operations combined with frequent ploughing are gradually causing the top soil to become more friable. Ashes have been mixed with the soil on one or two plots.

There is no subsoil water on the farm and the land is not liable to floods.

The farm has been used for sewage irrigation 36 years, and is managed by the Croydon Corporation.

The normal dry weather flow is about 600,000 gallons per 24 hours or 28·5 gallons per head of the population, the contributory districts being Shirley, South Norwood, and a portion of Upper Norwood with a combined population of 21,000 persons. The public water supply is about 25 gallons per head and is obtained from the same source as the Croydon water. The average annual rainfall is 24·04 in. The districts served by the sewers are exclusively on the w.c. system, there are no privies. The drainage area (built area) of the districts draining to the farm is about 1,200 acres and the streets are either macadam or gravel. The general sewerage system is in a very good condition, and the subsoil being a stiff retentive clay, reduces the subsoil leakage to a minimum. About two thirds of the streets sewered have duplicate sewers for surface water from streets and front portions of roofs.

There are no storm overflows, all the increases of flow due to storms being received and treated on the farm. These increases of flow are at times very great, sometimes exceeding a rate of 4,000,000 gallons per 24 hours, or nearly seven times the normal flow. The sewers are flushed with large automatic tanks, tipping tanks, and flushing vans and hose.

The whole of the sewage gravitates to the farm by four outfall sewers, one 2 ft. 9 in. by 2 ft. 3 in. two 24 in. and one 15 in. laid at gradients of 1 in 600, 1 in 400, and 1 in 500 respectively, and having a combined capacity when running full of 1,900 cubic feet a minute. The average time the sewage takes to reach the farm is one hour. The whole of the sewage (except that from the 15 in. low level sewers) on reaching the farm passes through two settling tanks constructed of burnt ballast concrete, and cement rendered, each 60 ft. long by 12 ft. by 3 ft. 4 in. (average depth) and have a working capacity of about 15,000 gallons each. They are provided with scumboards, fine and coarse screens ($\frac{1}{4}$ in and 1 in. spaces between the bars), and are both used together continuously. (Add. B. II.). No chemicals whatever are used. The tanks are cleaned out once a week by means of mechanical bucket elevators discharging into adjacent sludge bays. About 30 tons of wet sludge are produced on an average per week; part is sold and part is used to fill up holes in a disused brickyard on the farm. The sewage from the 15 in. low level sewer before going on to the land flows through a small tank or catch-pit on the lower part of the farm and is not screened, but it is not in large amount. About five tons of wet sludge are removed from this tank weekly by hand labour. Pumping is employed to raise the sewage 10, 14, or 24 feet to the higher portion of the farm (about 33 acres) which lies considerably above the level of the outfall sewers. The remainder of the area irrigated is commanded by gravitation. Two 5 in. Gwynne's centrifugal pumps are employed, in conjunction with a plunger

pump, all being driven by gas engines. The effluent from some of the land near the bottom of the farm, can if necessary be pumped on to the higher land, a 15in. underground pipe conveying the partially treated effluents back to the pump well. After leaving the tanks part of the settled sewage flows to the pump well, and is pumped to the high parts of the irrigation area, the balance passes on to the irrigation land by means of open carriers, half pipe and closed stoneware pipe carriers provided with openings at suitable intervals for turning the sewage on to the land. The flow of sewage on to the plots is regulated by wooden sluices placed in the manholes to which the carriers are connected. Iron and wooden stoppers are used for diverting the sewage on the land. The higher land on the farm has a somewhat sharp fall and the sewage is contoured over this land.

The total area of the farm is 191 acres (Add. B. I.); 152 acres are actually irrigated, and this area deals with 600,000 gallons of sewage (excluding storm water) per 24 hours. With the present population and 28·5 gallons of sewage per head this amounts to 138·15 persons, or about 4,000 gallons per acre. About one third of the total available irrigable area is used at one sewaging, which corresponds to about 12,000 gallons per acre per day.

Only about 25 acres of the farm are underdrained. The drains are laid at an average depth of about 2ft. being 4in. and 6in socketted pipes with open joints, the trenches being filled in with the soil excavated. They are about 12 yards apart, and were put in for the same purpose as at Beddington, *viz.*, to assist waterlogged plots to dry. The drain effluents are brought to the surface lower down the farm and re-treated. The sewage is treated on separate plots either two, three, or four times, being run over the surface of the land in a thin sheet, picked up in a carrier at the bottom of the plot, and passed over other plots in a similar manner, before the effluents leaves the farm. In times of storms solids are washed out on to the land in the vicinity of the carrier chambers and this tends to clog the land at these points. The number of times the sewage is treated varies according to the length and area of the plots; sewage which has passed over a long plot not requiring as much subsequent treatment as when it only flows a short distance and *vice versa.* The sewage is kept on the same plots continuously for from two to four days. In wet weather the area of land usually sewaged at one time is considerably enlarged, water from back roofs and yards sometimes bringing down 1·5 to 6 times the normal dry weather flow and causing the main outfall culvert to overflow, besides over-dosing the land with sewage.

The greater portion of the farm, as at Beddington, is laid down in rye-grass. Mangolds, oats and mint are also grown, part of the crops being sold and part of the rye-grass made into hay. The effluent leaves the farm by an open ditch joining the Chaffinch Beck a short distance away; the beck in dry weather has only a very small flow, and in winter it frequently does not exceed the volume of the effluent. A small amount of sewage weed was noticeable in places, but this may not be due to the effluent, but to surface water drains which flow into a ditch joining the effluent before reaching the Chaffinch Beck, the ditch itself containing similar weed. In summer a large amount of the effluent is absorbed or evaporated. In dry seasons very little effluent leaves the farm.

The total capital outlay on the farm up to the present date (1900) has been £54,302 2s. 3d. The cost per 1,000,000 gallons of sewage treated is, pumping and wages £1 15s. Inclusive of sinking fund, interest, and rent of portion of farm not freehold, £15 9s. 4d.

The average annual loss on the farm for the past five years has been £1,026 10s. 6d.

Annual loss - - - - - -	£1,026	10	6
Sinking fund and interest - - -	2,363	10	6
Total -	£3,390	1	0

The chief difficulty experienced in the working of the farm is the selling of the crops.

At the time of visiting the farm, bacteria beds (single contact) were being constructed, one small one being in active use and treating screened sewage. The effluents from these beds is passed over land and finally mixes with the general effluent on leaving the farm. All effluents other than general effluents are distinct from these bacterial effluents and have no connection with them. The general effluents all contain a certain amount of bacterial effluent, which, however, had been treated over land on leaving the beds.

Temperature and Rainfall Notes.

A large amount of rainfall occurred on both visits to the farm. The mean daily rainfall for the first visit was ·06 in., and for the second ·08 in. excluding rainfall during the experiment which averaged ·06 in. daily.

The mean daily maximum temperature was 6·9° C. (44·5° F.), for the first visit (January, 1900), with an average minimum of 1·4° C. (34·5° F.).

At the second visit during the experiment in November and December, 1900, the mean daily maximum was high, being 10·8° C. (51·5° F.), with a mean daily minimum of 4·2° C. (39·6° F.).

The period (November 7th to November 26th, 1900) immediately preceding the experiment was distinctly colder, the mean daily minimum being 2·9° C. (37·3° F.). A rainfall of ·42 in. was registered on the 17th November. (*See* Add. B. III., IV., & V.).

SOUTH NORWOOD SEWAGE FARM.

TABLE I.

(Domestic Sewage.)

Table showing all samples drawn at South Norwood.

Number of Sample.	Date of drawing sample.	Time of day.	Rainful day previous to drawing sample.	Rainfall day of drawing sample.	Atmospheric temp. time of drawing sample.	Temp. of sample.	Max. temp. during the 24 hours.	Min. temp. during the 24 hours.	Humidity (9 a.m.).	Dissolved oxygen in sample.	Brief description of sample.	Remarks.
	1900.		Inches.	Inches.	°C. °F	°C. °F.	°C. °F.	°C. °F.				
21	January -	2.15 p.m.	·07	·01		7·7 (46)	9.4 (49)	4·4 (40)			Screened and settled sewage - - -	*Mean daily max. temp. 6·9 °C. (44·5)°F.
22	9 „ -	3.15 „	·07	·01		6·1 (43)	9·4 (49)	4·4 (40)			First field effluent -	Mean daily min. temp. 1·4 °C. (34·5) °F.
23	9 „ -	5.15 „	·07	·01		4·4 (40)	9·4 (49)	4·4 (40)			Final effluent - - -	Mean daily rainfall ·06 in.
24	16 „ -	1.0 „	·18	·28		7·7 (46)	6·1 (43)	2·7 (37			Screened and settled sewage - - -	
25	16 „ -	2.0 „	·18	·28		6·6 (44)	6·1 (43)	2·7 (37)			First field effluent - -	*For the period June 8th to Jan. 30th, 1900.
26	16 „ -	3.0 „	·18	·28		5· (41)	6·1 (43)	2·7 (37)			Final effluent - - -	
27	16 „ -	2·45 „	·18	·28		6·6 (44)	6·1 (43)	2·7 (37)			First field effluent - -	
28	22 „ -	2.45 „	·00	17		7·7 (46)	8·3 (47)	1·6 (35)			Screened and settled sewage - - -	Note.—Samples which may have been affected by rainfall are underlined.
29	22 „ -	4.0 „	·00	·17		6·6 (44)	8·3 (47)	1·6 (35)			Second field effluent -	
30	22 „ -	4.45 „	·00	·17		7·2 (45)	8·3 (47)	1·6 (35)			Final effluent - - -	
31	30 „ -	4.0 „	*·24.(s.r)†	·03		3·3 (38)	3·8 (39)	3·3 (38)			§General effluent - -	† s.r. Signifies snow and rain.
32	30 „ -	4.45 „	„	·03		3·8 (39)	3·8 (39)	3·3 (38)			Brook water - - -	
33	30 „	5·0 „	„	·03		3·8 (39)	3·8 (39)	3·3 (38)			Brook water and effluent	§ By "general" effluent is meant a mixture of two or more finally treated effluents on leaving the farm.
34	30 „	5.30 „	„	·03		3·8 (39)	3·8 (39)	3·3 (38)			„	
35	29 „	3.30 „	·11 (s.r)	24 (s.r)		3·3 (38)	3·3 (38)	0·0 (32)			General effluent	
35A	5 February -	12.45 „				2·7 (37)					„	

170	7 November	12 (noon)	·015	·18	10· (50)	12·7 (55)	13·8 (57)	7·7 (46)	86		Crude sewage	
171	,,	2.30 p.m.	·015	·18	9·4 (49)	10· (50)	13·8 (57)	7·7 (46)	86	c.cs. 3·	Final effluent	Mean daily max. temp. 10·1°C.—(50·3)°F. Mean daily min. temp. 2·9°C.—(37·3)°F.
174	14 ,,	2.15 ,,	·08	·08	10·5 (51)	10·5 (51)	13·8 (57)	4·4 (40)	86	1·25	Street washings	Mean daily rainfall ·087 in. Mean daily humidity 82·7.
175	14 ,,	2.45 ,,	·08	·08	10·5 (51)	8·8 (48)	13·8 (57)	4·4 (40)	86	·3	Final effluent	
176	20 ,,	12 (noon)	·00	·05	6·6 (44)	11·1 (52)	9·4 (49)	·5 (33)	92		Screened and settled sewage	
177	20 ,,	1.0 p.m.	·00	·05	7·2 (45)	9·4 (49)	9·4 (49)	·5 (33)	92	·25	First field effluent	*For the period Nov. 7th to Nov. 25th, 1900.
178	20 ,,	3.0 ,,	·00	·05	7·2 (45)	6·6 (44)	9·4 (49)	·5 (33)	92	2·	Final effluent	
179	21 ,,	1.0 ,,	·05	·02	8·3 (47)	8·3 (47)	6·6 (44)	4·4 (40)	86		Street washings	
180	21 ,,	1.45 ,,	·05	·02	7·7 (46)	7·2 (45)	6·6 (44)	4·4 (40)	86	2·	Final effluent	
180B	23 ,,	1.0 ,,	·00	·00	7·2 (45)	7·2 (45)	10·5 (51)	8·8 (48)	74	3·50	Brook water and effluent	
180A	23 ,,	1.15 ,,	·00	·00	7·2 (45)	6·6 (44)	10·5 (51)	8·8 (48)	74		Final effluent	
					EXPERIMENT.							
181	27 ,,	2.15 ,,	·00	·03	12·2 (54)	8·8 (48)	11·6 (53)	2·7 (37)	85	1·	First field effluent	
181A	27 ,,	1.0 ,,	·00	·03	10·5 (51)	11·1 (52)	11·6 (53)	2·7 (37)	85		Screened and settled sewage	
182	28 ,,	12.45 ,,	·03	·08	8·8 (48)	9·4 (49)	12·2 (54) –	–1·1 (30)	98		Street washings	
183	28 ,,	1.30 ,,	·03	·08	8.8 (48)	7·7 (46)	12·2 (54) –	–1·1 (30)	98	1·	First field effluent	
184	28 ,,	2.15 ,,	·03	·08	9·4 (49)	7·7 (46)	12·2 (54) –	–1·1 (30)	98	·50	General effluent	
185A	29 ,,	1.0 ,	·08	·13	8·3 (47)	7·7 (46)	7·7 (46)	3·8 (39)	98	2·	First field effluent	
185	29 ,,	2.45 ,,	·08	·13	8.3 (47)	7·2 (45)	7·7 (46)	3·8 (39)	98	4·	Final effluent	
186A	30 ,,	11.30 a.m.	·13	·01	8 3 (47)	7·7 (46)	7·7 (46)	2·2 (36)	76	3·	First field effluent	Mean daily max temp. 10·8°C.—51·5)°F. Mean daily min. temp. 4·2°C –(39 6)°F.
186	30 ,,	11.45 ,,	·13	·01	8·3 (47)	7·2 (45)	7·7 (46)	2·2 (36)	76	1·	Final effluent	Mean daily rainfall ·063 in. Mean daily humidity 88·
187A	1 December	11.15 ,,	·01	·04	8·3 (47)	7·7 (46)	7·7 (46)	4·4 (40)	96		Street washings	
187B	1 ,,	11.30 ,,	·01	·04	8·3 (47)	7·7 (46)	7·7 (46)	4·4 (40)	96		First field effluent	
187C	1 ,,	1.30 p.m.	·01	·04	8·3 (47)	6·6 (44)	7·7 (46)	4·4 (40)	96		Final effluent	
187D	3 ,,	11.45 a.m.	·01	·00	6·6 (44)	7·2 (45)	6·6 (44)	2·7 (37)	92	·50	First field effluent	For the period Nov. 26th to Dec. 20th, 1900.
187	3 ,,	12.0 (noon)	·01	·00	6.6 (44)	6·6 (44)	6·6 (44)	2·7 (37)	92	·50	Final effluent	
188B	5 ,,	11.0 a.m.	·05	·20	15·5 (60)	9·4 (49)	17·7 (64)	8·8 (48)	96		Street washings	
188A	5 ,,	11.30 ,,	·05	·20	15·5 (60)	9·4 (49)	17·7 (64)	8·8 (48)	96		First field effluent	

SOUTH NORWOOD SEWAGE FARM.—*Cont.*

TABLE I.—*Cont.*

(Domestic Sewage).

Table showing all samples drawn at South Norwood.—*Cont.*

Number of Sample.	Date of drawing sample.	Time of day.	Rainfall day previous to drawing sample.	Rainfall day of drawing sample.	Atmospheric temp. time. of drawing sample.	Temp. of sample.	Max. temp. during the 24 hours	Min. temp. during the 24 hours.	Humidity (9 a.m.)	Dissolved oxygen in sample.	Brief description of sample.	Remarks.
	1900.		Inches.	Inches.	°C. °F.	°C. F.	C. °F.	°C. F.		c.cs.		
188	5 December	12.45 p.m.	·05	·20	15·5 (60)	9·4 (49)	17·7 (64)	8·8 (48)	96		Final effluent	
189A	7 ,,	11.0 a.m.	·136	·14	9·4 (49)	8·3 (47)	11·1 (52)	3·8 (39)	86	·25	First field effluent	
189	7 ,,	12.30 p.m.	·136	·14	9·4 (49)	7·2 (45)	11·1 (52)	3·8 (39)	86		Final effluent	
189B	8	11.0 a.m.	·14	·02			10· (50)	−1·1 (30)	93	·25	First field effluent	
189C	8 ,,	12·40 p.m.	·14	·02	11·1 (52)	8·3 (47)	10· (50)	−1·1 (30)	93	2·	Final effluent	
190	10 ,,	12 (noon)	·01	·01	9·4 (49)	7·7 (46)	11·6 (53)	2·2 (36)	86		First field effluent	
191	10 ,,	1.30 p.m.	·01	·01	10· (50)	6·6 (44)	11·6 (53)	2·2 (36)	86	1·50	Final effluent	
191A	11 ,,	11.20 a.m.	·01	·00	9·4 (49)	8·3 (47)	10·5 (51)	−1·6 (29)	93	·50	First field effluent	
192	11 ,,	1.0 p.m.	·01	·00	10· (50)	7·2 (45)	10·5 (51)	−1·6 (29)	93	1·75	Final effluent	
193A	13 ,,	11.0 a.m.	·00	·15	10· (50)	11·1 (52)	12·7 (55)	9·4 (49)	93		Screened and settled sewage	
193	13 ,,	12 (noon)	·00	·15	10· (50)	9·4 (49)	12·7 (55)	9·4 (49)	93		First field effluent	
194	13 ,,	1.0 p.m.	·00	·15	10·5 (51)	10· (50)	12·7 (55)	9·4 (49)	93		Final effluent	
194A	14 ,,	10.30 a.m.	·15	·03	10· (50)	8·3 (47)	10· (50)	3·8 (39)	79		First field effluent	
194B	14 ,,	11.30 ,,	·15	·03	10·5 (51)	6·1 (43)	10· (50)	3·8 (39)	79		Final effluent	

194C	15 December -	10·45 a.m.	·03	·01	10·5 (51)	9·4 (49)	11.6 (58)	8·8 (48)	93		First field effluent - -	
194D	15 „ -	11·45 „	·03	·01	10·5 (51)	9·4 (49)	11·6 (58)	8·8 (48)	93		Final effluent - - -	
195	17 „ -	11·0 „	·00	·00	8·3 (47)	7·2 (45)	11·1 (52)	5·5 (42)	86	1·50	First field effluent - -	
195A	17 „ -	12 (noon)	·00	·00	8·3 (47)	7·7 (46)	11·1 (52)	5·5 (42)	86		Final effluent - - -	
196	19 „ -	12·45 p.m.	·00	·30	7·2 (45)	8·3 (47)	10· (50)	1·6 (35)	95		First field effluent - -	
197	19 „ -	2·0 „	·00	·30	6·6 (44)	7·2 (45)	10· (50)	1·6 (35)	95		Final effluent - - -	
197A	20 „ -	12·40 „	·30	·01	10·0 (50)	8·8 (48	10·5 (51)	5· (41)	86		First field effluent - -	
198	20 „ -	1·40 „	·30	·01	10·5 (51)	8·8 (48)	10·5 (51)	5· (41)	86		Final effluent - - -	
	1901.											
199	2 January -	2·30 „	·01	·00	3·3 (38)	6·1 (43)	6·6 (44)	2·2 (36)	86		First field effluent -	
200	2 „ -	3·45 „	·01	·00	3·3 (39)	5·0 (41)	6.6 (44)	2·2 (36)	86		Final effluent - - -	
					END OF EXPERIMENT							
	1902											
453	14 January	5 p.m. Mon. to 4 p.m. Tues.	·00	00							Screened and settled sewage - - - -	24 hours samples.
454	15 „	5 p.m. Tues. to 4 p.m Wed.	·00	·00							„ „	
455	16 „	5 p.m. Wed. to 4 p.m. Thurs.	·00	·00							„ „	
456	17 „	5 p.m. Thurs. to 4 p.m. Fri.	00	·00							„ „	
457	18 „	5 p.m. Fri. to 4 p.m. Sat.	00	·00							„ „	
458	19 „	5 p.m. Sat. to 4 p m. Sun.	·00	00							„ „	
459	20 „	5 p.m. Sun. to 4 p.m. Mon.	·00	·00							„ „	

SOUTH NORWOOD SEWAGE FARM.

TABLE II.

(Domestic Sewage.)

Number of Sample.	Number of times the sewage was passed through or over the soil.	Area of plot or plots sewaged at the time of drawing sample.	Length of time those plots had been sewaged previously to drawing sample.	Nature of crops grown on plots.	Remarks.
		acres.			
22	once	6·5	3 days continuously	Rye-grass	Cloudy appearance, sewage smell.
23	3 times	1·3 1·0	3 days continuously	,,	Slightly cloudy, very slight sewage smell.
25	once	3·80	2 days continuously	,,	Cloudy, slight sewage smell.
26	twice	4·40	2 days continuously	,,	Fairly clear, no smell.
27	once	6·50	2 days continuously	Arable	Effluent rather cloudy.
29	twice	3·40 1·30	2 days continuously	Rye-grass	Opalescent effluent, no smell.
30	3 times	2·30	2 days continuously	,,	Fairly clear.
31	General effluent - - - - - - - - - - - -				,, ,, yellowish colour.
32	Water from Chaffinch Brook, taken 20 yds., above effluent outfall				Rather turbid.
33	,, ,, ,,		20 yds. below ,, ,,		,, ,, yellowish colour.
34	,, ,, ,,		466 yds. below No. 33		,, ,, ,, ,,
35	General effluent - - - - - - - - - - - -				Rather cloudy.
171	twice	3·80 4·40	2 days continuously	Rye-grass	Clear, no smell.
175	4 times	3·60, 1·30, 1·0, 1·75 arable	4 days	Rye and arable	Clear, no smell.
177	once	3·40	3 days	Rye-grass	Strong sewage smell.
178	3 times	2·40 1 70	3 days	,,	Slight ,, ,,
180	3 times	3·50, 1·25, 1·0	3 days	,,	Slight smell, yellowish colour.
180A	3 times	3·40, 1·30, 2·	2 days	,,	Slight smell, yellow colour.

EXPERIMENT.

181	once	·25	1 day	Arable	Surface effluent, cloudy.
183	once	·32	2 days	,,	,, ,, rather cloudy.
184					General effluent, cloudy, no smell.
185A	once	·40	3 ,,	,,	Surface effluent, fairly clear.
185	twice	·40 + ·10	2 ,,	,,	,, ,, clear, no smell.
186A	once	·46	4 ,,	,,	,, ,, fairly clear, no smell.
186	twice	·46 + ·12	3 ,,	,,	,, ,, no smell, clear.
187B	once	·55	5 ,,	,,	,, ,, fairly clear
187C	twice	·55 + ·18	4 ,,	,,	,, ,, no smell.
187D	once	·70	7 ,,	,,	,, ,, yellow colour, slight sewage smell.
187	twice	·70 + ·20	6 ,,	,,	,, ,, suspended matter.
188A	once	·80	9 ,,	,,	,, ,, sewage smell.
188	twice	·80 + ·24	8 ,,	,,	,, ,, slight sewage smell, rather cloudy.
189A	once	·88	11 ,,	,,	,, ,, sewage smell, cloudy.
189	twice	·88 + ·30	10 ,,	,,	,, ,, slight sewage smell, greenish yellow colour.
189B	once	1·25	12 ,,	,,	,, ,, strong sewage smell, cloudy, suspended matter.
189C	twice	1·0 + ·36	11 ,,	,,	,, ,, slight sewage smell, yellow colour.
190	once	1·16	14 ,,	,,	,, ,, sewage smell, cloudy.
191	twice	1·16 + ·38	13 ,,	,,	,, ,, slight smell, clear.
191A	once	1·18	15 ,,	,,	,, ,, sewage smell, fairly clear, yellow colour.
192	twice	1·18 + ·42	14 ,,	,,	,, ,, clear, yellow colour, slight sewage small.
193	once	1·20	17 ,,	,,	,, ,, sewage smell, cloudy.
194	twice	1·20 + ·50	16 ,,	,,	,, ,, rather cloudy, slight smell.
194A	once	1·20	18 ,,	,,	,, ,, cloudy, sewage smell.
194B	twice	1·20 + ·55	17 ,,	,,	,, ,, clear, yellow colour, slight smell.
194C	once	1·25	19 ,,	,,	,, ,, cloudy, sewage smell.
194D	twice	1·25 + ·58	18 ,,	,,	,, ,, suspended matter, cloudy.
195A	once	1·25	21 ,,	,,	,, ,, putrid smell cloudy.
195	twice	1·25 + ·58	20 ,,	,,	,, ,, slightly cloudy, no smell.
196	once	1.25	23 ,,	,,	,, ,, strong sewage smell, cloudy.
197	twice	1·25 + ·60	22 ,,	,,	,, ,, turbid, sewage smell
197A	once	1·25	24 ,,	,,	,, ,, strong sewage smell, cloudy.
198	twice	1·25 + ·70	23 ,,	,,	,, ,, sewage smell, yellow colour.
199	once	1·25	37 ,,	,,	,, ,, very foul effluent.
200	twice	1·25 + ·80	36 ,,	,,	,, ,, strong sewage smell.

SOUTH NORWOOD SEWAGE FARM.

(Domestic Sewage.)

Additional Notes on Samples.

Sample No. 27.—In this case, the furrows of one of the arable fields ran longitudinally with the flow of the sewage; thus effecting very little purification.

Sample No. 31.—The general effluent was flowing at the time of sampling at the rate of about 1½ million gallons per 24 hours, the rainfall had largely increasad the flow. NOTE.—All general effluents contain the bacteria bed effluents after they have been passed over the land.

Sample No. 32.—The Chaffinch Beck was flowing a good deal above the normal flow owing to recent rains. Rate of flow about 500,000 gallons per 24 hours, or in the proportion of 1 of stream water to 3 of effluent. The stream did not appear to be in very good condition. This sample was drawn 20 yards above the point where the effluent discharges into the stream. (Add. B. II.)

Sample No. 33.—This sample was drawn 20 yards below the effluent outfall. Some sewage weed below the effluent outfall at the sides of the stream.

Sample No. 34.—This sample was taken 466 yards below sample No. 33; no sewage weed observable.

Sample No. 175.—The sewage from which this effluent was obtained was treated over four separate plots.

Sample No. 174.—Surface water from streets and from front roofs, turbid, taken after sharp showers the day previous and also whilst drawing the sample.

Sample No. 179.—Surface water from streets after moderate showers, streets washed fairly clean, by previous rainfall.

Sample No. 180B.—Brook water (Chaffinch Beck) and effluent, taken 55yds. below effluent outfall, a good deal of sewage weed in the stream, volume of effluent to stream approximately as 3 to 1.

Sample No. 182. Surface water from streets, very full of grit and very turbid. Sample was drawn after the surface drain had been running for 3 hours, surface water channel contained whitish sewage weed.

Sample No. 187A.—Surface water from streets after a slight rainfall (·04in.).

Sample No. 188B.—As No. 187A, very turbid, sample taken after drain had been running for 4 hours (·20in. rainfall).

EXPERIMENT.

NOTE.—Two arable fields were employed for this experiment of the areas of 1·25 and 1·0 acres respectively. The land in question had a crop of mangolds during the summer, and had not been sewaged since February, 1900. No artificial manure had been applied; the plots were freshly ploughed about 8in. deep, and ridged 2 days before commencing the experiment. The sewage was treated twice, being run from the first on to the second plot. The quantity of sewage treated per acre per 24 hours was increased daily from 3,000 gallons the first day by equal increments of 1,500 gallons to 39,000 gallons on the 20th December. The second plot of arable received whatever effluent came off the first plot. The sewage was run on continuously both day and night, and not intermittently.

Sample No. 181.—The sewage was run on to the first plot at noon, November 26th, 3,750 gallons covering ·25 acre.

This sample was drawn from the effluent which had passed through the surface soil down to the clay subsoil and filtered through cracks in the latter to the pick-up grip at foot of plot. This grip was about 30 yds. from the nearest point where the oncoming sewage showed.

There was a very small flow of effluent and not sufficient to reach the second plot owing to the cracks in the soil. The sewage going on to the land was soapy and fairly strong.

Sample No. 183.—Sewage black and septic looking—partly, no doubt, owing to being backed up in the pipe carrier by the gauging board, some deposit taking place. A mere dribble of effluent going on to the second plot at noon.

Sample No. 185A.—Sewage about normal.

Sample No. 185.—This was a sample similar in all respects to No. 181. There was very little effluent coming off.

Samples Nos. 186A and 186.—Sewage about normal. Owing to the increased flow the sewage did not appear to be septic, and solids were not held back.

Samples Nos. 187B and 187C.—A large portion of the first plot had now been sewaged. Previously only a small area had been covered owing to small amount of sewage put on. The sewage had not yet reached the top of the plough cuts.

Samples Nos. 187D and 187.—Sewage rather dilute.

Samples Nos. 188A and 188.—Sewage very dilute.

Samples Nos. 189A and 189.—Sewage very dilute, most of it being rain water. Tanks cleaned out the day previous.

Samples Nos. 189B and 189C.—Sewage stronger than the previous day.

Samples Nos. 190B and 191.—Sewage normal.

Samples Nos. 191A and 192.—Sewage fairly strong.

Samples Nos. 193 and 194.—Sewage much stronger; a great deal of froth on the effluent from the first plot.

Samples Nos. 194A and 194B.—Sewage strong. A large part of the second plot had now received sewage.

Samples Nos. 194C and 194D.—Sewage normal.

Samples Nos. 195A and 195.—Sewage about normal. Land beginning to smell, sewage weed in pickup grip at bottom of first plot.

Samples Nos. 196 and 197.—Sewage normal.

Samples Nos. 197A and 198.—Rainfall on first plot caused the large flow on to the second plot Sewage very dilute.

Samples Nos. 199 and 200.—Sewage dilute. After increasing the amount on the first plot to a constant flow of about 39,000 gallons per acre per 24 hours, no more samples were drawn until January 2nd, 1901. The sewage had thus been flowing on to the two plots at the above rate for 12 days continuously night and day, and the plots appeared thoroughly over-worked, both effluents appearing foul. NOTE.—A diagram is appended showing the actual amounts of sewage treated per acre (Add. B. VI.)

SOUTH NORWOOD SEWAGE FARM.

TABLE III.

(Domestic Sewage).

Comparative Samples.

Effluent treated over one plot.	Effluents treated over two plots.	Effluents treated over three plots.	Remarks.
	No. 26 ,, 171	No. 23 ,, 30	By "comparative sample" is meant samples drawn from the same areas of land, and the effluents in brackets are comparable with each other so far as the area of land sewaged is concerned.
* No. 181 ,, 183 ,, 185A ,, 186A ,, 187B ,, 187D ,, 188A ,, 189A ,, 189B ,, 190 ,, 191A ,, 193 ,, 194A ,, 194C ,, 195A ,, 196 ,, 197A ,, 199 (Arable land.)	* No. 185 ,, 186 ,, 187C ,, 187 ,, 188 ,, 189 ,, 189C ,, 191 ,, 192 ,, 194 ,, 194B ,, 194D ,, 195 ,, 197 ,, 198 ,, 200 (Arable land.)		* Strictly speaking, the same daily areas of land were not sewaged until late in the experiment.

SOUTH NORWOOD SEWAGE FARM.

TABLE IV.

(Domestic Sewage).

Sewage Samples.

Number of sample.	Nature of sewage.	Time taken.	Remarks.
21	Screened and settled sewage.	2.15 p.m.	Dilute sewage.
24	,, ,, ,, ,,	1 p.m.	Somewhat dilute.
28	,, ,, ,, ,,	2.45 p.m.	,, ,,
170	Crude sewage.	noon.	A very soapy sewage.
176	Screened and settled sewage.	noon.	,, ,, ,,
181A	,, ,, ,, ,,	1 p.m.	Apparently fairly strong, very soapy.
193A	,, ,, ,, ,,	11 a.m.	Rather dilute.
453			
454			
455			
456	24 hours samples.		
457			
458			
459			

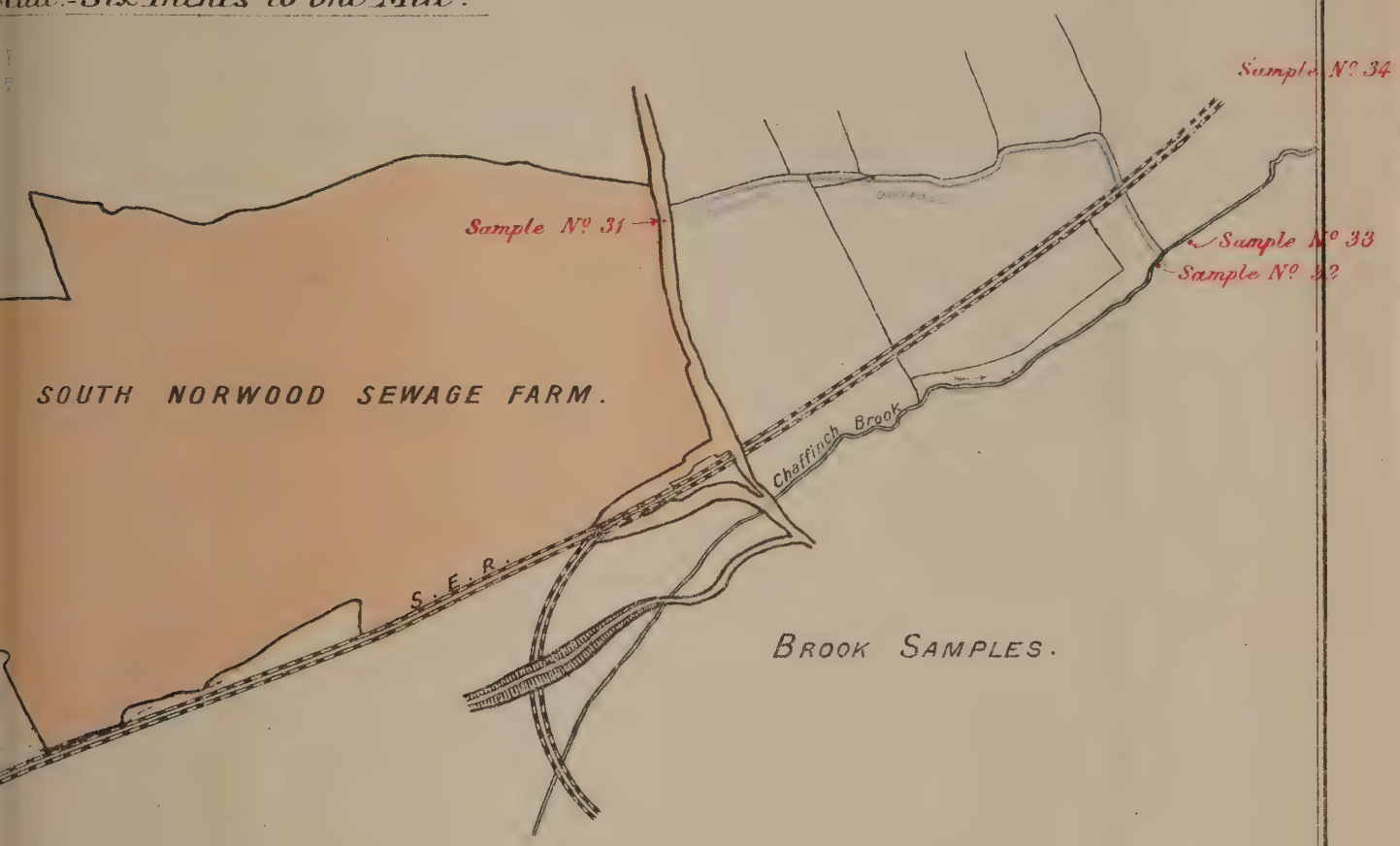
South Norwood Sewage Farm.

This Map was supplied by Mr Walker. Borough Engineer of Croydon:-

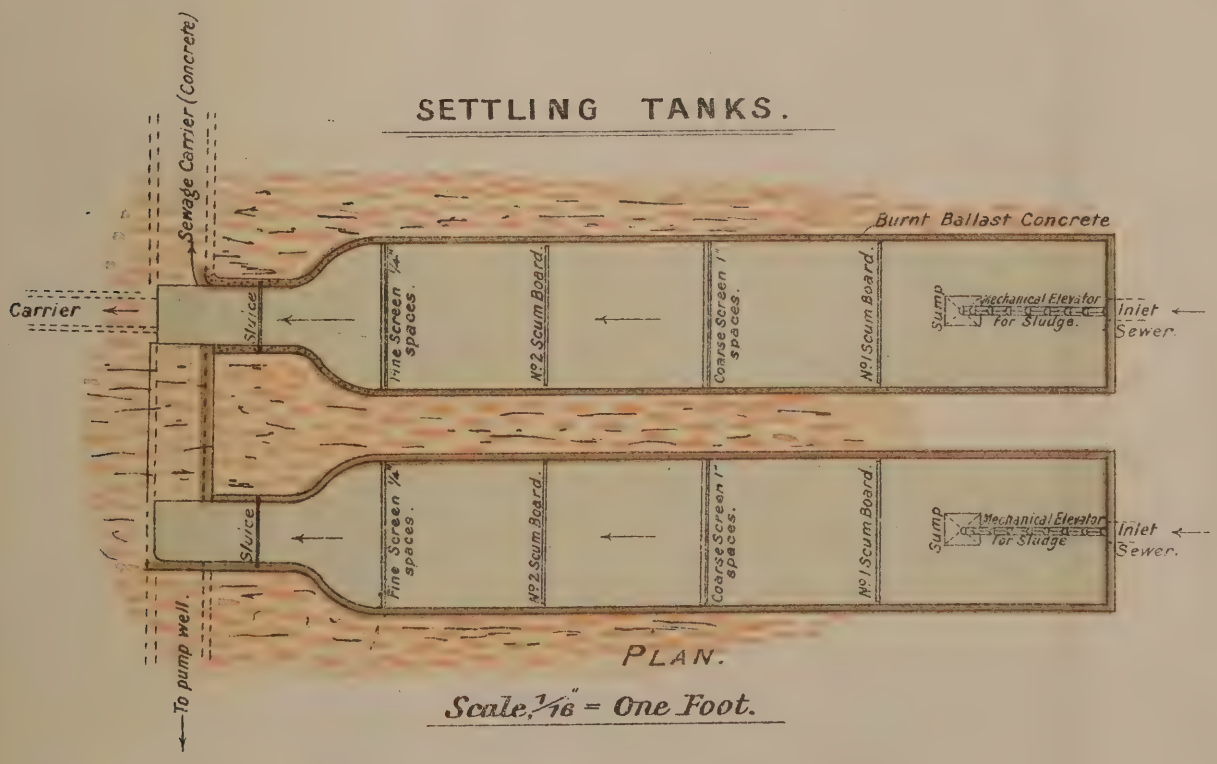
Weller & Graham Ltd Litho London

SOUTH NORWOOD SEWAGE FARM.

Scale:- Six Inches to one Mile.



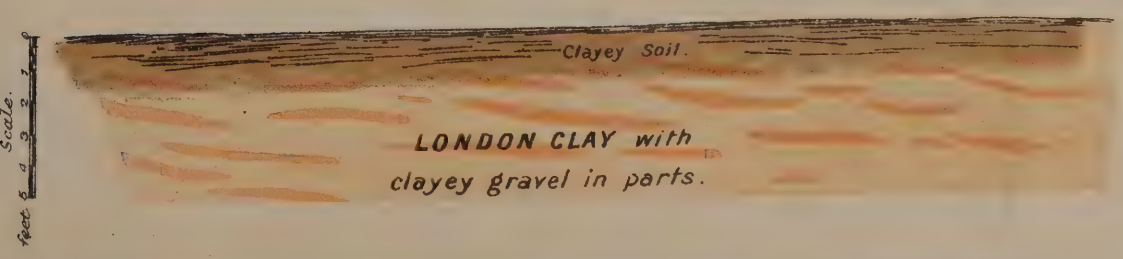
SETTLING TANKS.



PLAN.

Scale, 1/16" = One Foot.

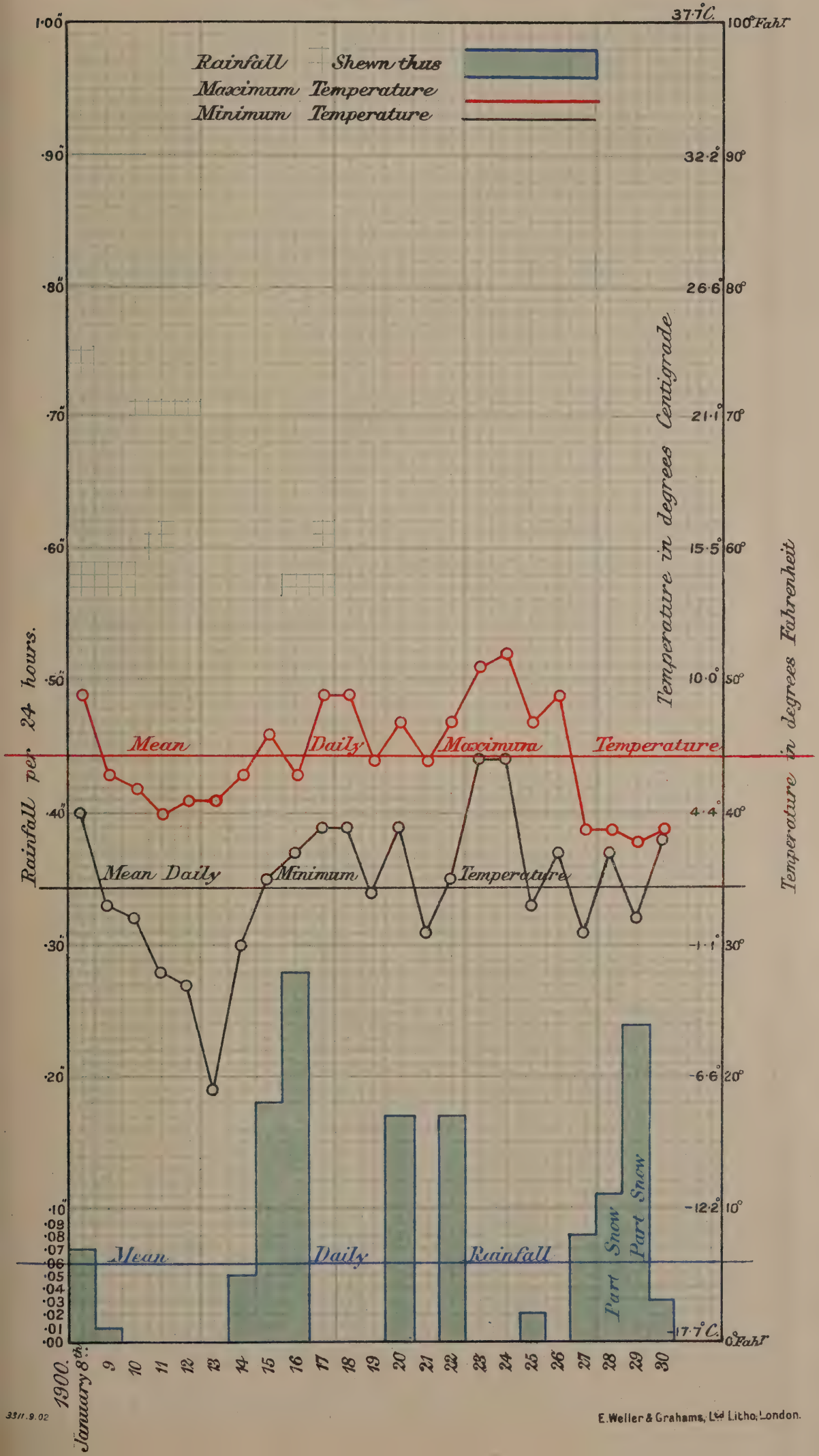
SECTION OF SOIL & SUBSOIL.



9311 8 02
Weller & Graham Ltd Litho.

SOUTH NORWOOD SEWAGE FARM.

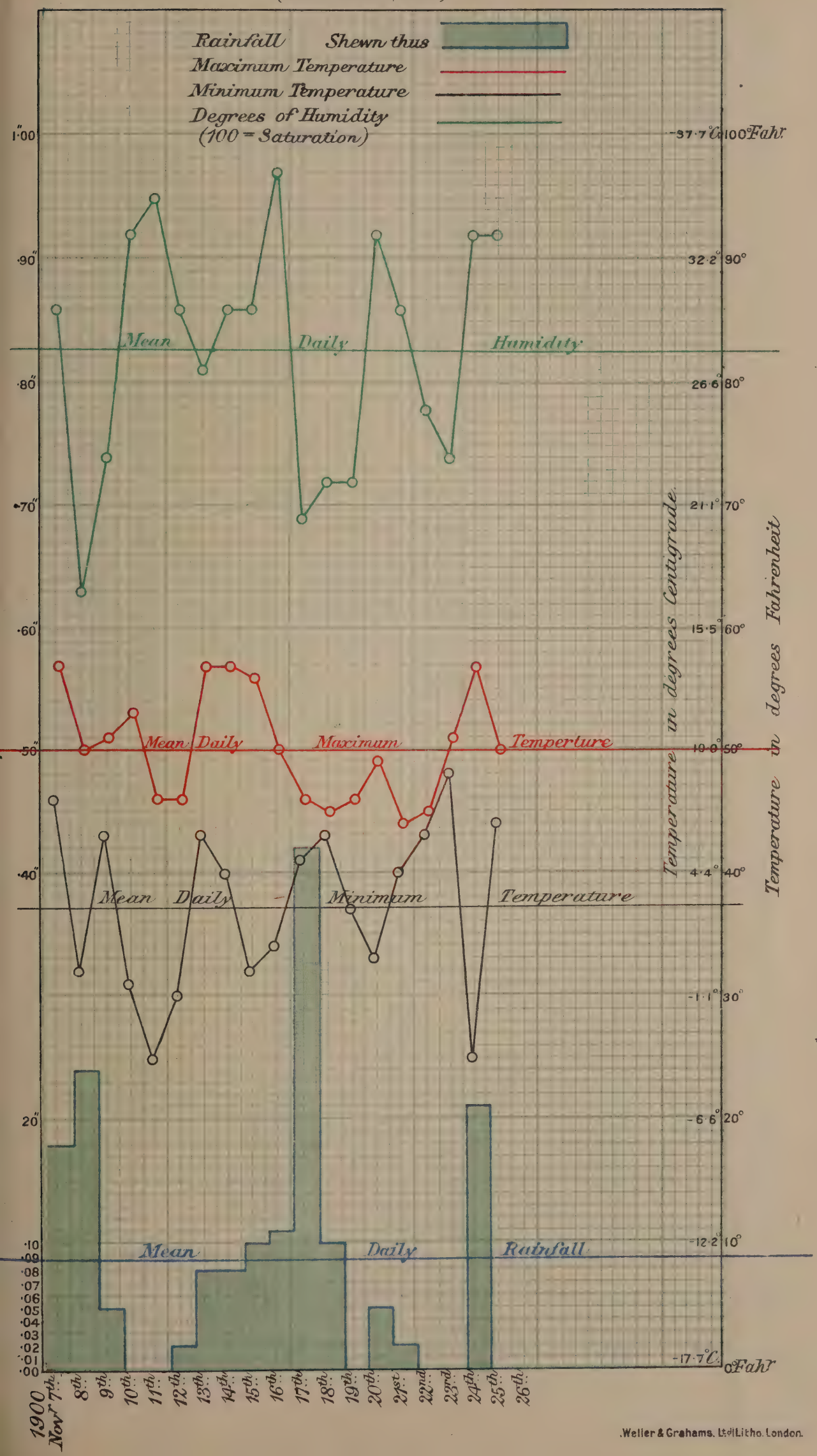
(First visit)



33/1.9.02
E. Weller & Grahams, Ltd Litho, London.

SOUTH NORWOOD SEWAGE FARM.

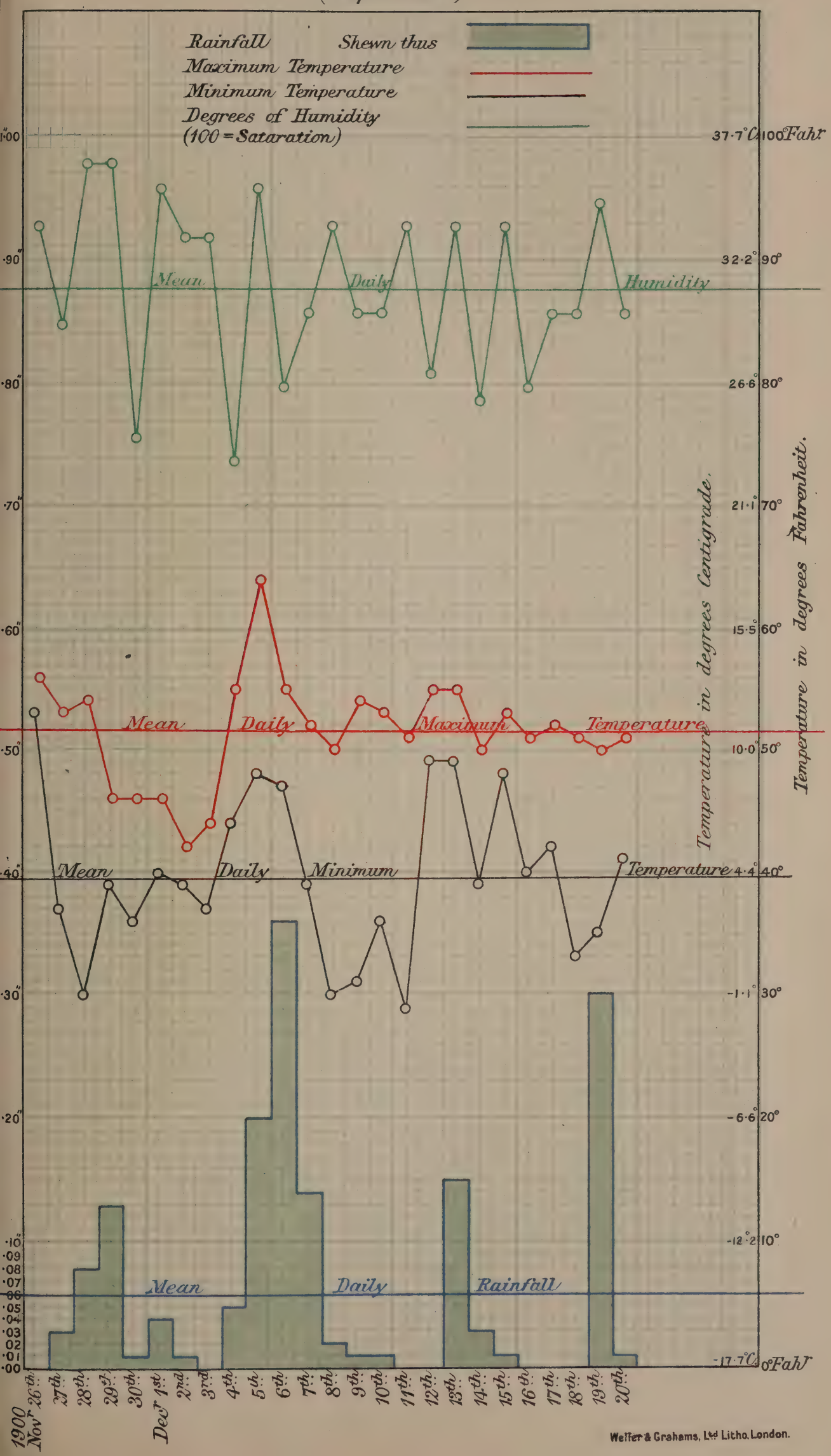
(Second Visit)



Weller & Grahams. Ltd Litho. London.

SOUTH NORWOOD SEWAGE FARM.

(Experiment)



Weller & Grahams, Ltd Litho. London.

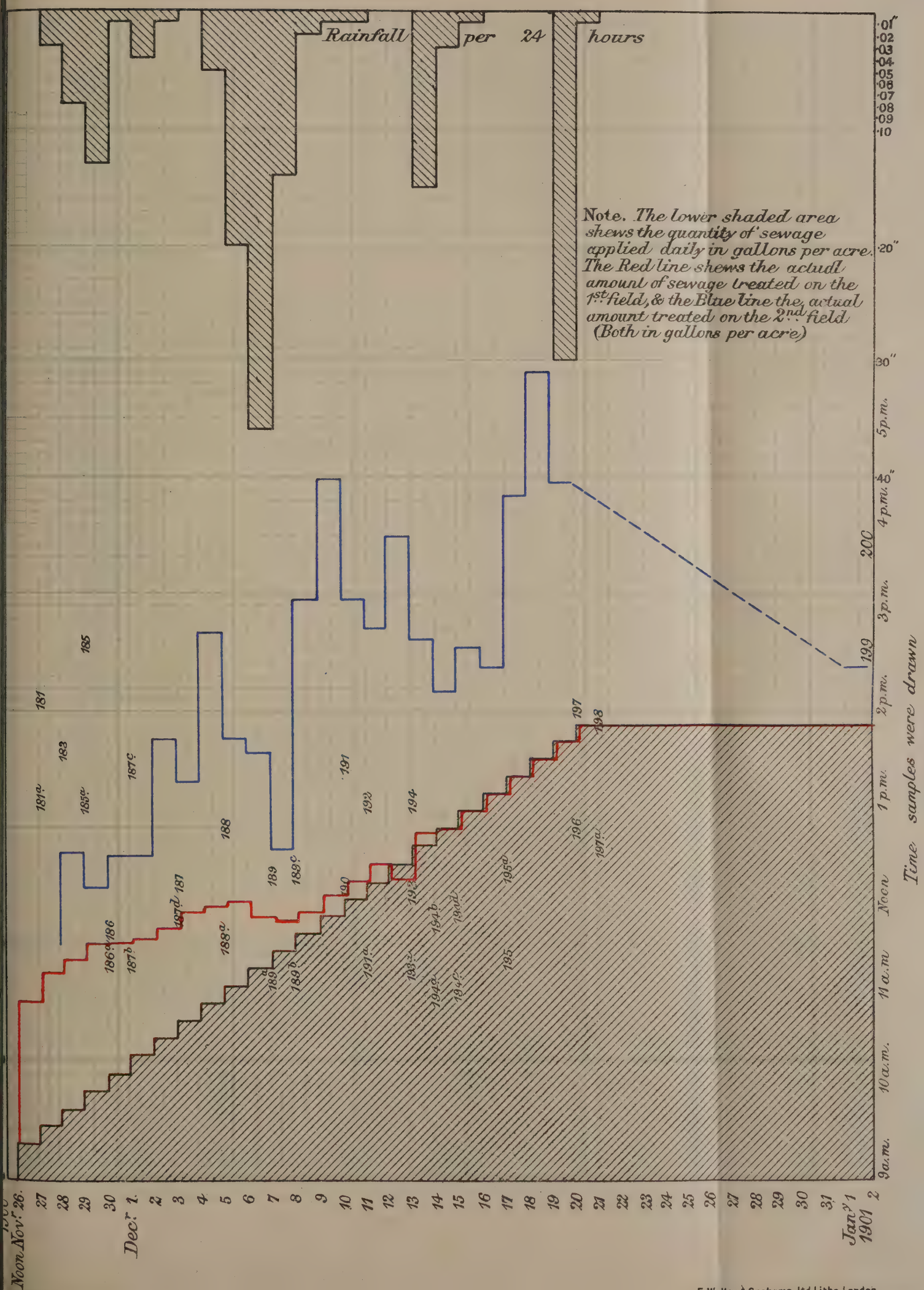
Diagram No. 30.
(Engineering Report Diagram)

Addendum B.

VI.

SOUTH NORWOOD SEWAGE FARM.

(Experiment)



LUTON SEWAGE FARM REPORT.

SUMMARY OF CONTENTS.

Description of Farm.

Addendum A—Notes on Samples.

Table I.—Shewing all samples drawn at the Luton Sewage Farm, together with time of drawing, rainfall, temperatures, description of samples, etc.

Addendum B—

I.—Section shewing pits from which effluents were drawn.

LUTON SEWAGE FARM.

(Luton Corporation.)

(Domestic Sewage and refuse from Straw-plait industry.)

The sewage is treated by means of screening, settling tanks, and land filtration, the entire effluent being absorbed by the chalk.

There are two farms, the High Level and the Low Level. The former has been working for 16 years, and the Low Level for 23 years.

Both farms overlie the Chalk formation. The surface soil on the High Level farm (which is situated on a hill) varies greatly, increasing in depth towards the foot of the hill. About 4in. to 10in. appears to be the depth of surface soil on the crown of the hill, whilst a depth of several feet is reached in the valley. The surface soil is loose porous loam. The Low Level farm has from 10in. to 15in. of good loamy soil, and in parts a subsoil of gravel resting on the chalk.

The surface chalk under both farms is exceedingly loose, rotten, and full of cracks. The average daily flow of sewage per 24 hours pumped for the year ended December 31st, 1899, was about 1,700,000 gallons, inclusive of storm water. The population draining to the two farms is about 38,500. Approximtely one-fourth of the streets have a separate system for storm water. The average annual rainfall from 1888 to 1899 was about 25 ins.

About one-third of the total sewage flow is trade refuse from the straw-plait industry. This refuse is derived from bleaching (peroxide of hydrogen and silicate of soda are used) and dye refuse (logwood, etc.), also a large quantity of gelatine. The refuse, beyond being screened and run through sumps to arrest solids, is not treated in any way by the manufacturer before entering the sewers.

The sewage gravitates to the pumping station and is pumped to the farms. The sewage is passed through roughing screens before being pumped, to guard against injury to the pumps. The tanks at the pumping station have a combined capacity of about 1·75 million gallons, and act as storage tanks when pumping is suspended. They are cleaned out once a fortnight. One tank is kept in reserve for storms.

The sludge tanks on the High Level farms have a combined capacity of about 1,500 cube yards of wet sludge. They are formed in the ground itself, the bottom of the tanks resting on the chalk. They are cleaned out about three times a year. Farmers cart the sludge away, and pay from 4d. to 6d. per cube yard according to the quantity removed.

The total area of the Low Level farm is 17·5 acres, with an irrigable area of 14 acres. That of the High Level farm is 71 acres, with an irrigable area of 56 acres, the total available irrigable area being 70 acres. About 20 acres are irrigated at one time on the High Level farm. The area of land irrigated at one time on the Low Level farm varies, the whole 14 acres are used on Sundays and in times of rainfall.

The sewage is run on to the same area for about 12 hours as a rule by day, and for 6 to 12 hours by night, according to the weather. It is usually kept on the same area for about a month, sometimes as long as two months.

A large part of the land under irrigation is laid out in narrow beds planted with various crops, the sewage being run into the channels between the beds. The hilly portion of the High Level farm being unsuited to this system, is chiefly laid out in rye grass, the sewage flowing over the surface of the land, and being absorbed in the chalk in a short distance.

The filtration of the sewage through the chalk appears to be almost vertical, as may be seen from the following experiment which was carried out.

In order to obtain samples of the effluent two pits were dug in the hilly portion of the High Level farm, their size being about 7ft. by 3ft. by 9ft. deep. A small embankment was formed round the edge of each, and the sewage run right round the pits. None of the effluent, however, entered either of the pits, although the sewage was running on within 2ft. of the

holes. Subsequently a recess was cut (see section Add. B. I.) in the side of one of the pits next to the sewage, and the sewage was directed into a small pocket or hole immediately above the recess, the surface soil having been removed and the chalk bared. By this means effluents were obtained from sweatings or drippings through the chalk roof of the recess. Three samples of soil were taken near these pits, where the surface soil was about 12in. in depth. One sample was taken 6in. to 8in. deep, one sample of the chalk lying 1in. to 4in. below the base of the surface soil, also another of the chalk about 12in. deeper. The land from which these samples were drawn had been sewaged ten days previously. Samples were also drawn from a well, and from springs in the immediate vicinity of the sewage farms.

The direction of the flow of the underground water through the chalk, as given by Mr. Joseph Lucas in his hydro-geological survey, shews that the spring and well samples are in the line of flow.

LUTON

TABLE I.

No. of sample.	Date of drawing sample.	Time of drawing sample.	Rainfall day of drawing sample.	Air temperature time of drawing sample.	Temperature of sample.	Brief description of sample.	Remarks
				°C. °F.	°C. °F.		
240	March 19th, 1901 -	Noon - -	Slight rain and snow -	3·3 (38)	7·7 (46)	Spring water - -	Spring water taken from watercress beds below the Sewage Farm; a clear sample.
241	" " -	12.15 p.m. -	" " -	3·8 (39)	8·3 (47)	" " - -	Mixture of springs feeding watercress beds, water clear.
242	" " -	12.45 " -	" " -	3·3 (38)	7·7 (46)	Well water - - -	*Well water from cottages below farm. Well 20 ft. deep, 2 ft. water. Water only fairly clear.
243	March 27th, 1901 -	3.30 " -	Slight rain - - -	3·3 (38)	7·7 (46)	Spring water - -	This sample was drawn from the same place as No. 240.
244	" " -	3.45 " .	" " - - -	2·7 (37)	7·7 (46)	Well water - - -	This sample was drawn from the same well as No. 242. Water in well 2 ft. deep, and water contained some sediment.
244A	" "	3.0 " -	" " - - -	1·1 (34)	10· (50)	Crude sewage - -	A good deal of dye refuse, blue-black colour.
409	November 5th, 1901 -	3.30 " -	Some rain - - -	4·4 (40)	10· (50)	Filtration effluent -	This effluent was collected from a pit dug in the chalk (*see sketch*). The sewage had previously passed over a length of rye-grass of about 30 ft., finally filtering through from 2 ft. 6 ins. to 3 ft. of loose rotten chalk into the pit. Slight sewage smell, turbid.
410	November 7th, 1901 -	11.15 a.m. -	No rain - - - -	8·8 (48)	10· (50)	Well water - - -	From same well as Nos. 242 and 244. Water in well 1 ft. 3 in. deep. Sample a chalky-blue colour, containing some finely divided suspended matter.
411	" " -	1.0 p.m. -	" " - - - - -	10· (50)	11·1 (52)	Settled sewage - -	This sample was taken from small recess at the head of the pit immediately before filtering through. Apparently a weak sewage containing some dye refuse.
412	" " -	1.15 " -	" " - - -	10· (50)	9·4 (49)	Filtration effluent -	The same as No. 411, but after passing vertically through about 3 ft. 6 in. of loose chalk. Turbid, slight sewage smell.
413	November 11th, 1901	12.30 " -	" " - - - - -	12·2 (54)	11·6 (53)	Settled sewage - -	This sample was taken from the same place as No. 211. Some dye refuse.
414	" "	1.0 " -	" " - - - - -	12·2 (54)	10· (50)	Filtration effluent -	Taken in a similar way to No. 412. Turbid, chalky colour.
441	December 12th, 1901	3.30 " -	Very heavy rain during drawing of sample	8·3 (47)	5· (41)	Settled sewage - -	Taken in the same way as No. 413. Contained dye refuse.
442	" "	3.40 " -	" " "	7·2 (45)	3·8 (39)	Filtration effluent -	Rye grass immediately above pit last sewaged on December 11th, 1901. Resulting effluent from No. 441 through about 3 ft. 6 in. of loose chalk. This effluent took about 1½ minutes to pass through the chalk.

DATA CONCERNING THE LUTON SEWAGE FARM.

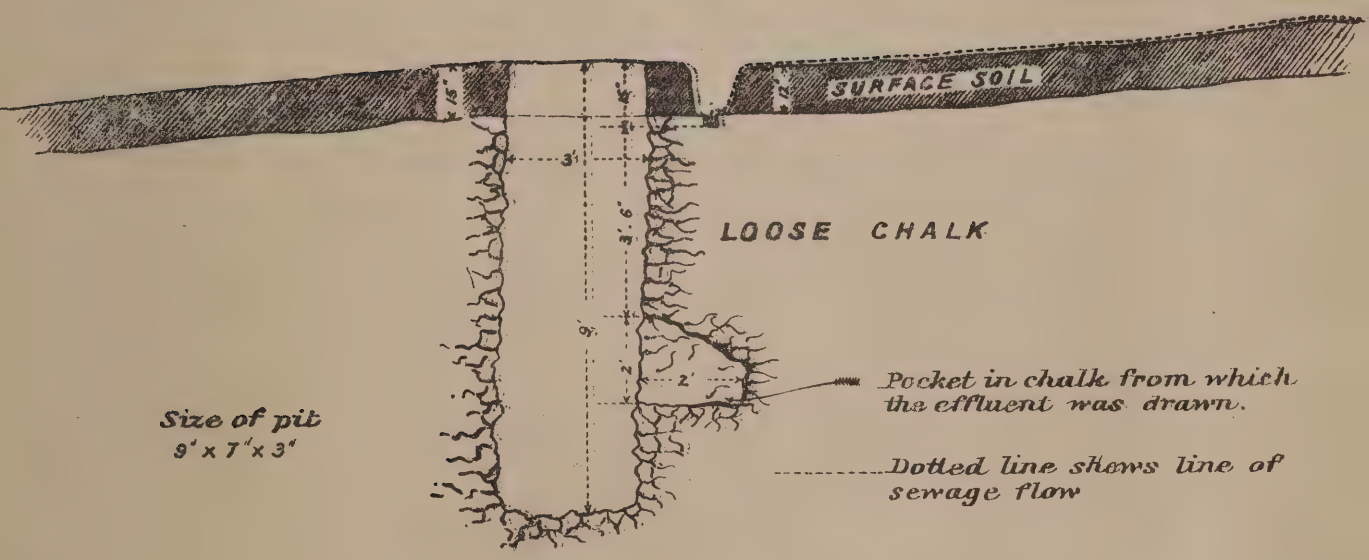
Population draining to farm - - - - - - -	About 38,500.
Water supply per head - - - - - - - -	" 24 gallons.
Average sewage flow per 24 hours (including rainfall) -	1,700,000 "
Nature of trade refuse - - - - - - - -	Bleach and dye refuse.
Treatment of sewage - - - - - - - - -	Screening and setting tanks, then pumped to the Farm, the lift being from 42 ft. to 125 ft., and run down grips between the beds on which the crops are grown, except in the case of rye-grass, when it flows over the entire surface.
Average annual rainfall (1888 to 1899) - - - -	25·3 ins.
Sewerage system - - - - - - - - - -	Partially separate.
Area of crops on Farm year ending September 1899 -	79 acres.
Principal crop - - - - - - - - - -	Rye-grass.

* NOTE.—This well was dry-steined, and used as drinking water by two cottages. Formerly privies were used, but after a case of typhoid fever had occurred, they were converted to tub closets. The contents of these closets were, however, still used as a manure for garden crops growing in the immediate vicinity of the well.

LUTON SEWAGE FARM.

SECTION OF PIT FROM WHICH EFFLUENTS WERE DRAWN.

Scale.-Four Feet to an Inch.



SECTION.

WORSLEY SEWAGE FARM REPORT.

SUMMARY OF CONTENTS.

DESCRIPTION OF FARM.

Addendum A.—Notes on Samples.

Table I.—Sewage Samples.

Table II.—Comparative Samples.

Table III.—Giving area of plots from which effluents were drawn and the time those plots had been under sewage, etc.

Table IV.—Showing all samples drawn at the Worsley Sewage Farm, together with time of drawing, rainfall, temperatures, description of samples, etc.

Additional Notes on Samples.

Addendum B.

I.—Temperature, rainfall, and humidity chart.

WORSLEY SEWAGE FARM (BARTON OLD HALL).

(Worsley Urban District Council).

(Domestic Sewage with Dye and Bleach Refuse.)

The total area of this farm is 127 acres, of which 40 acres are laid out for irrigation. At the time of visiting the farm, however, only 22 acres were available for sewage treatment owing to cropping operations. The population draining to this farm is 10,000, and the dry weather sewage flow 300,000 gallons per 24 hours. The water supply is obtained from the Bolton and Manchester supply. Dye and bleach refuse form a considerable portion of the sewage; the actual proportion of trade refuse has not been ascertained. The sewerage system is partially separate. No tanks, screens, or chemicals are employed, the sewage running crude on to the land.

The irrigable land is underdrained about 5 feet deep, 40 to 50 yards apart, with socketted stoneware pipes, the pipes being laid parallel, and the trenches filled with the material excavated. The northern part of the farm, consists of gravel and sandy soil, fairly suitable for sewage purification, the largest portion of the sewage being treated on this area. The southern part of the farm borders on the peat land, and consists chiefly of pure peat of considerable depth; there is practically no surface soil with the exception of a few scattered patches here and there formed by the decay of the exposed peat and vegetation. Where the section of the soil is exposed, the peat at a depth of from 5 feet to 6 feet lies on a bed of exceedingly fine white sand. The average area under irrigation at one time is from 8 to 10 acres, the sewage usually being kept on this area for from 12 to 15 hours. This area with a total sewage flow of 300,000 gallons per 24 hours gives 15,000 to 23,500 gallons treated per acre per 24 hours.

The effluent produced by the upper portion of the farm appeared of a fair quality, that from the peat land, although clear in appearance, smelt strongly of sewage, and the ditch into which the effluent pipes discharged smelt very much of sulphuretted hydrogen. This ditch, which is continued into the main effluent ditch, leads into a small stream about 15 feet wide, called the Parrin Brook; this stream at the time of visiting the farm (May, 1901) was in a very bad condition, the bed being covered with black mud, and a large amount of sewage weed. The chief pollution appeared to be received some distance before reaching the farm; and it seems that another sewage farm also discharges its effluent into this stream before it reaches the Worsley Sewage Farm. The present area of the farm has been in operation (May, 1901) about 4 years.

There was no rainfall of any account during the time that samples were drawn at Worsley, with the exception of May 26th, on which day ·15-inch fell and ·04-inch on the following day; these were the only two days on which rain fell, the weather being for the rest of the time very hot and dry.

TABLE I.

SEWAGE SAMPLES.

Number of Sample.	Nature of Sewage.	Character.	Time taken.	Remarks.
277	Containing dye refuse -	Crude sewage -	11.45 a.m.	Neither screened or settled—dark, blackish colour.
281	- ditto - ditto - -	- ditto - -	4.15 p.m.	Neither screened or settled—dark, blackish colour.
285	- ditto - ditto - -	- ditto - -	12.0 (noon)	Neither screened or settled—very black looking.

TABLE. II.

* COMPARATIVE SAMPLES (or Samples taken from the same Plots of Land).

Number of Sample.	Remarks.
278 - - - - 280 - - - - 282 - - - - 286 - - - -	* By comparative samples is meant samples drawn from the same areas of land, and the effluents in brackets are comparable with each other so far as the area of land is concerned.

TABLE III.

EFFLUENTS and other Samples—(not Sewage).

Number of Sample.	Number of times the Sewage is passed through the Soil.	Area of Plot or Plots Sewaged at the time of drawing Sample.	Length of time these Plots had been Sewaged previous to drawing Sample.	Nature of Crops Grown on Plots.	Remarks.
		Acres.			
278	Once - -	7·50	2½ days - -	Rye and various coarse grasses.	Yellow colour, slight sewage smell—final effluent.
279	—	—	—	—	Liquor from peat-land — yellowish colour.
280a	—	—	—	—	Brook water and effluent taken 20 yards below effluent outfall—muddy colour.
280	Once - -	7·50	—	Rye and coarse grass.	Yellow colour, slight smell—final effluent.
282	Once - -	7·50	12 hours - -	Rye and coarse grass.	Reddish yellow colour, sewage and iron smell—final effluent.
283	—	—	—	—	Liquor from peat-land—yellow colour.
284	—	—	—	—	Brook water above effluent outfall—muddy, dirty colour.
286	Once - -	7·50	12 hours - -	Rye and other grasses.	Final effluent, yellow colour, sewage smell.
287	Once - -	8·50	15 hours - -	Rye and other grasses.	Final effluent, yellow colour, but no smell, from gravel soil.
288	—	—	—	—	Brook water above effluent outfall—yellowish colour.
289	—	—	—	—	Brook water and effluent taken 100 yards below effluent outfall.
290	—	—	—	—	Peat liquor, dirty yellow colour.

WORSLEY URBAN DISTRICT COUNCIL.

TABLE IV.

BARTON OLD HALL SEWAGE FARM.

(Domestic Sewage and Dye Refuse.)

Number of Sample.	Date of Drawing Sample.	Time of day.	Rainfall day previous to Drawing Sample.	Rainfall day of Drawing Sample.	Air Temperature time of Drawing Sample.	Temperature of Sample.	Maximum Temperature during the 24 hours.	Minimum Temperature during the 24 hours.	Humidity (9 a.m.)	Dissolved Oxygen in Sample.	Brief description of Sample.	Remarks.
	1901.		Inches.	Inches.	°C. °F.	°C. °F.	°C. °F.	°C. °F.		c. c.s		
277	May 13th - -	11.45 a.m.	·00	·00	15·5 (60)	13·3 (56)	31·1 (88)	1·6 (35)	58	—	Crude sewage - - -	
278	,, - -	12.15 p.m.	·00	·00	15·5 (60)	8·8 (48)	31·1 (88)	1·6 (35)	58	—	Final effluent - - -	
279	May 15th - -	12.0 (noon)	·00	00	18·3 (65)	12·2 (54)	31·6 (89)	4·4 (40)	93	—	Peat liquor - - - -	
280	,, - -	12.15 p.m.	·00	·00	18·3 (65)	10· (50)	31·6 (89)	4·4 (40)	93	—	Final effluent - -	
280a	,, - -	12.45 ,,	·00	·00	19·4 (67)	11·6 (53)	31·6 (89)	4·4 (40)	93	—	Brook water and effluent -	Mean daily Maximum Temperature, 26·9°C. 80·55°F.
281	May 20th - -	4.15 ,,	·00	·00	21·1 (70)	13·3 (56)	24·4 (76)	0·0 (32)	68	—	Crude sewage - - -	Mean daily Minimum Temperature, 4·5°C. (40·11)°F.
282	,, -	5.30 ,,	·00	·00	20·5 (69)	13·8 (57)	24·4 (76)	0·0 (32)	68	—	Final effluent - -	Mean daily Humidity, 69·0.
283	,, - -	4.25 ,,	·00	·00	21·1 (70)	15·5 (60)	24·4 (76)	0·0 (32)	68	-	Peat liquor - - -	Mean daily Rainfall, ·01 in.
284	,, - -	4.45 ,,	·00	·00	21·1 (70)	15· (59)	24·4 (76)	0·0 (32)	68	—	Brook water - - -	For the period—May 12th to May 29th, 1901.
285	May 28th - -	12.0 (noon)	·04	·00	23·3 (74)	15·5 (60)	19·4 (67)	7·2 (45)	64	—	Crude sewage - - -	NOTE.—Samples which may have been affected by rainfall are underlined.
286	,, - -	1.20 p.m.	,,	·00	24·4 (76)	15·5 (60)	19·4 (67)	7·2 (45)	64	—	Final effluent - - -	
287	,, - -	1.0 ,,	,,	·00	25·5 (78)	14·4 (58)	19·4 (67)	7·2 (45)	64	—	Final effluent - - -	
288	,, - -	12.35 ,,	,,	·00	26·6 (80)	17·7 (64)	19·4 (67)	7·2 (45)	64	—	Brook water - - -	
289	,, - -	12.45 ,,	,,	·00	26·6 (80)	17·7 (64)	19·4 (67)	7·2 (45)	64		Brook water and effluent -	
290	,, - -	12.15 ,,	,,	·00	24·4 (76)	15·1 (61)	19·4 (67)	7·5 (45)	64	—	Peat liquor - - - -	

WORSLEY SEWAGE FARM.

(Barton Old Hall)

3311. 9. 02.

Waller & Grahams, Ltd Litho. London.

Worsley Sewage Farm.

Additional Notes on Different Samples.

Sample No. 277.—This sewage appeared to contain a large quantity of dye refuse.

No. 278.—Final effluent from peat land. There was scarcely any surface soil whatever, the decayed peat forming the greater portion. In cuttings where visible, the peat at a depth of 5 to 6 feet was lying upon a layer of very fine white sand.

The land sewaged had not been finally levelled, and consequently the sewage had a tendency to pond in some parts.

The plot was covered with coarse herbage, chiefly grass and water plants.

No. 279.—This sample was drawn from water draining from the peat into an open ditch. It is difficult to state definitely whether this ditch had ever been polluted by sewage or effluent. The manager said that it had not been, to the best of his knowledge, and judging from the appearance and position of the spot it seemed unlikely.

No. 280a.—Brook water and effluent; the brook appeared to be in a very bad condition, both above and below the effluent outfall; the bed of the stream was covered with black mud, and there was a large amount of sewage weed present. The manager stated that another sewage farm effluent empties into this stream before it receives the Worsley effluent. The sample was a dirty muddy colour. The effluent outfall discharges at right angles to the stream, and both appeared well mixed. The brook joins the ship canal further down.

No. 287.—Final effluent. This was a sample drawn from another portion of the farm, where the soil was composed of sand and gravel but no peat, and fairly suitable for sewage treatment.

It appeared to be a fair average sample of the effluent which the better portions of the farm turn out.

HEMSWORTH SEWAGE FARM REPORT.

SUMMARY OF CONTENTS.

Description of Farm.

Addendum A.—Notes on Samples.

Table I.—Shewing all samples drawn at the Hemsworth sewage farm, together with time of drawing, rainfall, temperatures, description of samples, etc.

Table II.—Shewing area of plots from which effluents were drawn and the time those plots had been under sewage, etc.

Addendum B.

I.—Temperature, rainfall and humidity chart.

HEMSWORTH SEWAGE FARM.

Hemsworth Rural District Council.

(Domestic Sewage.)

The farm consists of a long narrow strip of land situated near the bottom of a steep slope on the Boulder Clay formation, and is four acres in extent, three acres of which are available for irrigation purposes.

The population draining to this farm is about 3,200, and forms part of a colliery district; the flow per 24 hours is about 70,000 gallons. The water supply is obtained from Barnsley Waterworks.

A small amount of slaughter-house refuse comes down the sewers on Wednesday, but there is no other trade refuse.

The whole of the sewage gravitates by a 15-inch sewer to the upper side of the farm, where the settling tanks are placed. Just before the outfall sewer enters the tanks there is a storm overflow leading to the same ditch into which the effluent discharges. The cill of this overflow is placed about 6½ inches above the invert of the outfall sewer. Thus the overflow would come into operation before half the carrying capacity of the sewer had been reached. The settling tanks are six in number, three being used at one time in series. Alumino-ferric is occasionally used to assist sedimentation.

The sizes of the tanks are :—

16 ft. by 15 ft. by 3 ft. 4½ in. deep
14 ft. by 15 ft. by 3 ft. 4½ in. ,, } in duplicate.
12 ft. by 15 ft. by 3 ft. 4½ in. ,,

Floating matter is kept back by a fixed scum board placed across the tanks and dipping into the sewage.

Floating draw-off arms are provided for drawing off the surface water for sludging purposes.

The settled sewage flows over a cill in the last tank into the main carrier running along the highest side of the farm.

The sludge from the tanks is drawn off by gravitation into three sludge bays adjoining the tanks, where it is mixed with ashes. About five tons are produced per week. Difficulty is experienced in disposing of the sludge, particularly in summer, as it cannot be put upon the grass crops.

The soil immediately adjoining the farm has a surface soil of 1½ inches to 2½ inches in depth, overlying about six feet of stiff yellow clay which lies upon the Boulder Clay. The land cracks badly in summer, but not so much in winter.

The land irrigated has been laid out in level terraces or beds, and the narrowness of the farm (about 70 yards) only admits of two beds before the effluent ditch is reached at the bottom of the farm. These beds have been underdrained at a depth of three feet, four drains to each bed, the drains being 18 feet apart, those of the upper beds discharging on to the surface of the lower one, and thence by an effluent outfall to the ditch which receives the whole of the effluent. In addition to the underdrainage, stone rubble to a depth of 6 inches has been filled in immediately above the drains, and also ashes above the rubble. Ashes have also been dug into the beds with a view to lightening them. The sewage passes from the main carrier through the first or highest bed, and is discharged from the underdrains on to the surface of the second bed. It is thus treated twice before going off the farm.

The beds from which the samples were drawn were not cropped and were frequently dug over. They receive sewage for periods ranging from one to seven days, according to circumstances. The effluent resulting from the treatment appeared to be very little purified, and one sample (294), from a sewage which contained a quantity of soap-suds, was very little different in appearance from the original sewage. The ditch into which the effluent flows would be almost dry in summer but for the effluent, and there were large quantities of sewage weed, whilst the effluent smelt badly. The shape of the farm and the fact that the fall runs across the narrow portion make effective treatment a difficult matter.

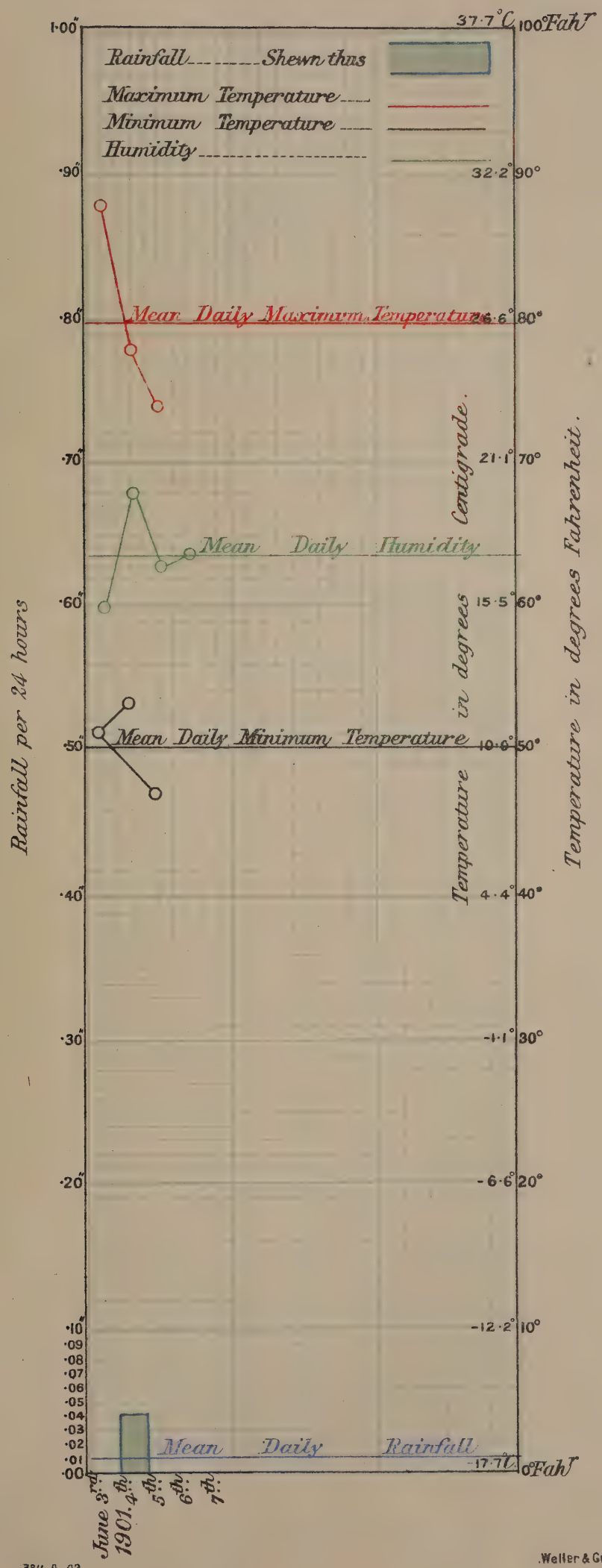
To purify sewage on an exceedingly stiff clay soil is at all times a difficult matter, the only possible method as a rule being surface treatment.

In the present instance the bulk of the work is done by filtration through the pervious material immediately above the drains, instead of being evenly distributed throughout the beds.

If the farm lay down the slope instead of across the bottom of it this could be easily carried out by lifting the settled sewage from the present settling tanks to the highest portion of the farm.

Again the amount treated per acre is very excessive. If one half of the whole irrigable area were employed in one sewaging (which is not the case), the amount treated per acre would be $\frac{70000}{1.5}$ = about 46,000 gallons per acre, and this is more than seven times the amount such land is usually called upon to treat.

HEMSWORTH R.D.C.



3911. 9. 02.
Weller & Grahams. Ltd Litho. London.

HEMSWORTH SEWAGE FARM.

(Domestic Sewage).

TABLE I.

Number of Sample.	Date of drawing Sample.	Time of day.	Rainfall day previous to drawing Sample.	Rainfall day of Drawing Sample.	Air Temperature time of Drawing Sample.	Temperature of Sample.	Maximum Temperature during the 24 hours.	Minimum Temperature during the 24 hours.	Humidity 9 a.m.	Dissolved Oxygen in Sample.	Brief description of Sample.	Remarks.
	1901.				°C. °F.	°C. °F.	°C. °F.	°C. °F.		c.c. s.		
291	June 4th - -	10.15 a.m. - -	·00″	·04″	19·4 (67)	17·2 (63)	25·5 (78)	11·6 (53)	68	—	Settled Sewage -	Soapy sewage, after passing through tanks.
292	„ „ - -	11.30 „ - -	„	„	21·1 (70)	15·5 (60)	„ „	„ „	„	—	Final Effluent -	Turbid, sewage smell.
293	„ 5th . -	10 15 „ - -	·04″	·00″	15·5 (60)	13·3 (56)	23·3 (74)	8·3 (47)	63	—	Crude Sewage -	Soapy—alumino ferric being used.
294	„ „ - -	11 15 „ - -	„	„	16·1 (61)	16·6 (62)	„ „	„ „	„	—	Final Effluent -	Cloudy, strong sewage smell.
												Mean daily Maximum Temperature 25·6 °C. (80°) F. „ „ Minimum „ 10·1 C°. (50·3°) F. „ „ Humidity - - - 63·75 „ „ Rainfall - - - ·01″ For the period June 3rd to June 6th, 1901. NOTE.—Samples which may have been affected by rainfall are underlined.

EFFLUENTS.

TABLE II.

No. of Sample.	Number of times the Sewage has passed through the soil.	Area of plot or plots sewaged at the time of drawing Sample.	Length of time these plots had been sewaged.	Nature of crops grown on plots.	Remarks.
292	Twice - - - - - -	About ·25 acre - - - - -	5 days - - - - - -	No crops - - - - - -	Effluent a dirty muddy colour, after passing through two successive clay beds.
294	„ - - - -	„ „ - - - -	6 „ - - - - - -	„ - - - - - -	Effluent turned a milky colour on entering ditch, after passing through two clay beds.

DERBY COUNTY ASYLUM SEWAGE FARM REPORT.

SUMMARY OF CONTENTS.

DESCRIPTION OF FARM.

Addendum A.—Notes on Samples.

Table I.—Showing all samples drawn at the Derby County Asylum Sewage Farm together with time of drawing, rainfall, temperatures, description of samples, etc.

Table II.—Giving Area of plots from which effluents were drawn, and the time those plots had been under sewage.

Addendum B.

I.—Rainfall, temperature, and humidity chart.

DERBY COUNTY ASYLUM SEWAGE FARM.

(Domestic Sewage.)

DERBY COUNTY COUNCIL.

This farm adjoins the Asylum buildings.

The soil of the entire farm is of a stiff nature, overlying a subsoil of red clay, and is derived from the Keuper Marl formation. It has never been properly laid out for sewage. The surface soil has a depth of about 3in. to 4in. where the land has been untouched.

About 25 acres are available for irrigation. The water supply is obtained from a deep well in the Asylum premises, an average of 50,000 gallons being pumped daily. The sewage flow per 24 hours was not gauged, but from the amount of water pumped it would appear to be about 30,000 gallons per 24 hours. The land is not sewaged within 150 yards of the well. There are two outfall sewers leading on to the farm, one of which takes the domestic sewage from the Asylum, and the other the liquid manure from the farmyards. The latter is collected in a tank before reaching the farm, and can be let off by a valve when required, or carted away to fields where wanted; (see sample No. 296); both sewages are treated together on the farm. The Asylum sewage, before running on to the land, passes through a small screening chamber, and there passes through a cage screen. There is no other preliminary treatment. The screenings obtained are dug into the land. The number of inmates in the Asylum varies from 800 to 1,000. A certain amount of roof and gulley water from the farmyard buildings enters the sewers, otherwise the system is separate, the Asylum roof water being collected in tanks for domestic purposes.

The land is underdrained about 3ft. 6in. deep with ordinary butt-jointed agricultural tiles 3in. and 4in. diameter, joining a master drain of stoneware socketted pipes 6in. to 9in. in diameter, and discharging into a ditch near the boundary of the farm.

The land appears to crack very much during the dry weather. No rye grass is grown, but the chief crops are mangolds and ox cabbage, with a few turnips and some prickly comfrey.

The land cropped and sewaged is ridged.

The sewage is brought on to the land by a stoneware carrier running along the top of the land, and flows from the carrier down the furrow between two ridges until it reaches the bottom of the plot, when it is turned into the next furrow, and the one previously sewaged is blocked up. About one acre per 24 hours is used, the entire flow of sewage being run on as described above. There did not appear to be any accumulations of sludge on the surface of the land. The ditch into which the effluent discharged appeared at the time of the visit to be in a fairly clear condition, and there was no sewage weed observable; this ditch was a dry one formerly, and cattle drink the effluent in the neighbouring fields. At the point where Sample No. 301 was drawn, another small ditch, of about half the volume of the effluent, joined the effluent ditch; the effluent appeared to improve during the passage along the ditch, settlement taking place, but no nuisance was observed arising from it. The suspended matter appeared to consist mainly of partially digested hay and straw, and was doubtless derived from the farmyard manure being treated and gaining entrance to the under-drainage through cracks in the soil and subsoil.

These under-drains prevent any effective treatment of the sewage, and aggravate the cracking of the soil which takes place in hot weather. If there were no under-drains, and a larger area of land were employed at one sewaging, there would probably be no effluent in dry weather.

On the assumption that the dry weather flow is 30,000 gallons, this quantity is treated on one acre for one day of 24 hours; thus putting heavy clay land on the same basis as the best porous soil.

Under the present conditions, the sewage as soon as it is applied to the land has a tendency to pass off through cracks to the under-drains insufficiently purified.

DERBY COUNTY ASYLUM SEWAGE FARM.

(Domestic Sewage).

TABLE I.

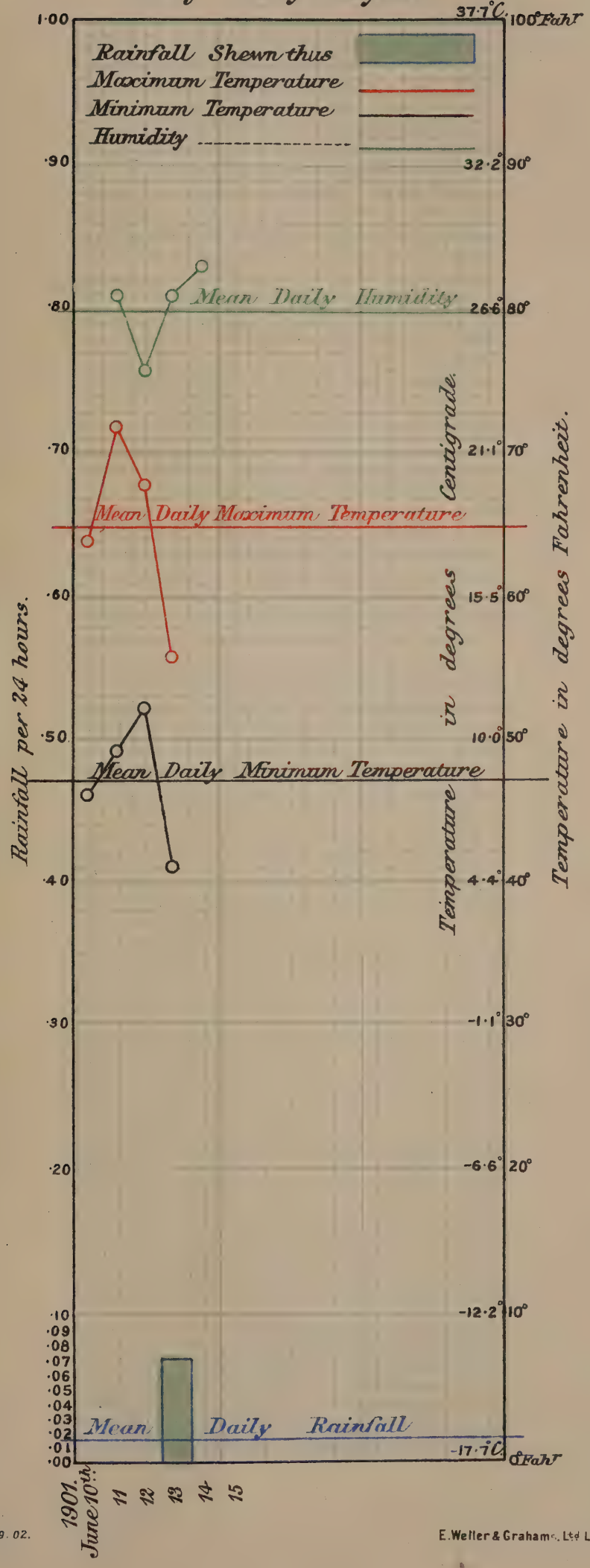
Number of Sample.	Date of drawing Sample.	Time of Day.	Rainfall day previous to drawing Sample.	Rainfall day of drawing Sample.	Air Temperature time of drawing Sample.	Temperature of Sample.	Maximum Temperature during the 24 hours.	Minimum Temperature during the 24 hours.	Humidity (9 a.m.)	Dissolved Oxygen in Sample.	Brief Description of Sample.	Remarks.
	1901.				°C. °F.	°C. °F.	°C. °F.	°C. °F.		c.cs.		
295	June 11th - -	10.55 a.m.	.00″	·00″	14·4 (58)	17·7 (64)	22·2 (72)	9·4 (49)	81	—	Screened Sewage -	Soapy appearance.
296	,, ,,	12.0 noon	,,	,,	14·4 (58)	10· (50)	,, ,,	,, ,,	,,	—	Final Effluent -	Turbid, no smell.
297	,, 12th - -	11.15 a.m.	.00″	·00″	13·3 (56)	10· (50)	20· (68)	11·1 (52)	76	—	,, ,, -	Dirty colour, suspended matter.
298	,, ,,	11.45 a.m.	,,	,,	13·3 (56)	11·1 (52)	,, ,,	,, ,,	,,	—	,, ,, -	Same effluent as No. 297 but taken 300 yds. further down ditch.
299	,, 13th - -	10.55 a.m.	.00″	·07″	8·8 (48)	11·1 (52)	13·3 (56)	5· (41)	81	—	,, ,, -	Yellow colour.
300	,, ,,	11.30 a.m.	,,	,,	10· (50)	11·1 (52)	,, ,,	,, ,,	,,	—	,, ,, -	Same effluent as No. 299 but taken 300 yds. further down ditch.
301	,, ,,	12.0 noon	,,	,,	10· (50)	10· (50)	,, ,,	,, ,,	,,	—	,, ,, -	,, ,, ,, 600 yds.
												Mean Maximum Temperature 18·3° C. (65)°F. ,, Minimum ,, 8·3° C (47)°F. ,, Humidity - - - - 80·2 ,, Rainfall - - - - ·014in. For the period June 10th to June 14th, 1901.

TABLE II.

No. of Sample.	Number of times the Sewage has passed through the soil.	Area of plot or plots sewaged at the time of drawing Sample.	Length of time these plots had been sewaged previously to drawing Sample.	Nature of crops grown on plots.	Remarks.
296	Once - - - - - -	About 1 acre - - -	6 hours - - - - -	Mangolds (ridged) - -	Effluent appeared to be insufficiently filtered, *i.e.*, a lot of suspended matter.
297	,, - - - - - -	,, , - - -	1 day - - - - - -	,, ,, - -	,, ,, ,, ,, ,, some partially digested hay in sample having apparently reached the drains through cracks.*
298	,, - - - - - -	,, ,, - - -	,, - - - - - -	,, ,, - -	As No. 297, but taken 300 yards further down the effluent ditch to show increased aëration (if any). The ditch alluded to contained nothing but effluent.
299	,, - - - - - -	,, - - -	6 hours - - - - -	Turnips (just up) - -	Effluent yellow colour—no smell.
300	,, - - - - - -	- -	,, - - - - -	,, ,, - -	Taken in the same way as No. 298 at the same place. Less suspended matter than in No. 299 owing to settlement in ditch.
301	,, - - - - - -	,, - - -	,, - - - - -	,, ,, - -	Sample same as No. 299, but taken 600 yards further down the ditch.

* The farmyard manure was turned on from 4 p.m. to 6.30 p.m. the previous evening, probably accounting for the presence of the suspended matter alluded to above, and showing the presence of large cracks in the soil, through which some of the sewage escapes to the drains practically untreated.

Derby County Asylum.



3311. 9. 02.

E. Weller & Graham, Ltd Litho London.

SANDHURST SEWAGE FARM.

LINDFIELD SEWAGE FARM.

ANDOVER (Dr. Poore's System).

SANDHURST SEWAGE FARM.

No. of Sample.	Date of drawing Sample.	Time of drawing Sample.	Rainfall day of drawing Sample.	Air temperature time of drawing Sample.	Temperature of Sample.	Brief description of Sample.	REMARKS.
				° C. ° F.	° C. ° F.		
61	April 4th, 1900 - - -	Noon - - -	No rain. ·30-inch day previous.	—	8·8 (48)	Screened and settled sewage.	Rather weak.
62	" " - - -	1.30 p.m. - -	" "	—	13·3 (56)	First field effluent.	A surface effluent from rye grass, a small plot about 40 feet long. This effluent had a sewage smell.
63	" " - - -	3.0 " -	" "	—	10·0 (50)	Final effluent. -	A filtration effluent after treatment through another rye grass plot.

DATA CONCERNING SANDHURST SEWAGE FARM.

Area of farm - - - - - - - -	13 acres.
Nature of soil and subsoil - - - - - -	Similar to the Camp Farm, but of rather a better nature, and more top soil.
Population - - - - - - - - -	600 to 700.
Underdrains - - - - - - - - -	3 feet deep.
Sewage flows per 24 hours - - - - - -	About 15,000 gallons.
Principal crops - - - - - - - -	Rye grass and mangolds.
Method of treatment - - - - - - -	As at the Camp Farm—passed through settling tanks (in duplicate) before coming on to the land

LINDFIELD SEWAGE FARM.

				° C. ° F.	° C. ° F.		
79	May 21st, 1900 - - -	3.35 p.m. - -	No rain - -	16·6 (62)	11·6 (53)	Final effluent -	Filtration effluent from 1·75 acre plot sown mangolds (just up). Effluent had a slight sewage smell.
80	" " - - -	3.50 " - -	" " - -	16·6 (62)	11·6 (53)	Settled sewage -	Apparently containing a good deal of subsoil water.
91	June 21st, 1900 - - -	12.55 " - -	" " - -	26·6 (80)	11·6 (53)	" " -	Very soapy; washing day.
92	" " - - -	2.20 " - -	" " - -	28·8 (84)	11·6 (53)	Final effluent -	From ·75 acres osiers; filtration effluent; slight sewage smell.

Area of farm - - - - - - - - 8 Acres. Entire area of farm underdrained 4 feet deep. A stiff clayey soil overlaying clay; very liable to crack in hot weather. Sewage first passed through settling tanks before going on to the land.

ANDOVER.

				° C. ° F.	° C. ° F.		
415	December 13th, 1901 - -	1.45 p.m. - -	A slight drizzle -	7·7 (46)	9·4 (49)	Well water - -	From shallow well in garden. Three feet of water in well. Two feet from ground level to water level. Well formed of concrete tubes.
416	" " - -	3.0 " - -	" " -	6·6 (44)	8·8 (48)	Filter water - -	Rain-water from artificial filter.

NOTE:—The plots in the garden vary in size from about 12 to 21 rods, and they receive the clearings from privies of 20 cottages, or about 100 persons, which are dug in. It takes from about 6 months upwards to finish one plot according to the size. All kinds of greens are grown, and can be planted a few days after the solids have been dug in. A plot which was in process of being manured in October, 1901, will probably be manured again in 1905. There is a good depth of soil (about 4 feet) in the garden overlaying the chalk. At the time of drawing the sample from the well, solids were being trenched in about 50 feet distant from the well itself. Total area now cultivated—about 5¼ roods.

APPENDIX A.

Notes on Air, Sewage and Effluent Temperatures.

Diagram 1, showing daily air, sewage and effluent temperatures at Nottingham.

Diagram 2, showing daily air, sewage and effluent temperatures at Aldershot Camp.

Diagram 3, showing daily air, sewage and effluent temperatures at Croydon (Beddington).

Diagram 4, showing daily air, sewage and effluent temperatures at South Norwood.

Diagram 5, showing mean monthly temperatures of air, sewage and effluent at Nottingham, Aldershot Camp, Croydon (Beddington) and South Norwood.

AIR, SEWAGE AND EFFLUENT TEMPERATURES.*

Systematic observations relating to atmospheric, sewage, and effluent temperatures were taken daily for a period of one year, at four of the eight farms visited. These temperatures were taken to ascertain (1) how different temperatures affect the purification; (2) the difference between the temperatures of the effluents, sewage and air at one time; (3) the difference between the effluent temperatures from "surface irrigation" as compared with "filtration" sewage farms, and (4) the relation between (*a*) the air temperatures, and (*b*) the effluent temperatures at (a^1) "surface irrigation,' and at (b^1) "filtration" farms.

At two of the farms, Nottingham and Aldershot Camp, the sewage is treated by means of filtration, whilst at South Norwood and Beddington surface irrigation is in vogue.

The character of the soils and subsoils peculiar to each farm are given below, and also the average depths of the underdrains.

Name.	Soil and Subsoil.	Average depth of Drains.
Nottingham - - - -	Light sandy loam and gravel overlying gravel and sand.	6 feet.
Aldershot Camp - - -	Sand (Bagshot Sand) - - -	3 feet 3 inches.
Croydon (Beddington) - -	Gravelly loam over gravel and sand -	Very few drains.
South Norwood - - -	Clay soil resting on London Clay -	Very few drains.

The daily temperatures relating to atmosphere (in the shade), sewage, and effluent, were taken about noon, and are given in full for each of the four farms in the accompanying diagrams. The monthly averages have been worked out from these, and are given in other diagrams (appended), as the relations the temperatures bear to each other are thus more easily followed.

It will be observed that the temperatures were taken at practically the same time every day. With reference to this it may be noted that the difference between the value of the soil temperatures taken at one hour only during the day, and the mean for that day does not appear to be material except at shallow depths (say up to 15 inches). This would however affect the surface irrigation farms to some extent, and would tend to show the effluent temperatures higher than the actual mean for the day, taking the effluent temperature as being practically the same as the soil.

From the diagrams it will be noticed that, broadly speaking, the effluent temperatures in the case of the surface irrigation farms follow the variations of the air temperature, whereas the filtration effluents are not similarly affected. In March and October the effluent and air temperatures on all the four farms approximate each other closely. In the case of the filtration farms, the effluents from October to March are warmer than the air, whilst with the surface irrigation farms the reverse obtain throughout the year. The temperature of the effluents in many cases proved to be a very fair index of the amount of surface irrigation and filtration respectively, taking place at each of the different farms visited.

The mean temperatures for the year at each of the four farms are appended.

* I desire to acknowledge my indebtedness to Mr. William Marriott, Assistant Secretary of the Royal Meteorological Society, for valuable suggestions.—G.B.K.

	Air in the shade.	Sewage.	Effluent.
Nottingham	11·4 °C. (52·6° F.)	15·8° C. (60·5° F.)	9·6°C. (49·4° F.)
Aldershot Camp	12·1° (53·9°)	11·0° (51·9°)	9·7° (49·5°)
Croydon (Beddington)	13·5° (56·4°)	13·3° (56·2°)	12·1° (53·9°)
South Norwood	13·1° (55·7°)	11·6° (52·9°)	10·8° (51·5°)

The difference between the mean effluent temperature for the year at Nottingham and Aldershot Camp, taken at 6 feet and 3 feet 3 inches deep respectively, was only ·056° C. (·1° F.). The greatest range in the Nottingham mean monthly effluent temperature was 7·15° C. (12·9° F.); at Aldershot Camp it was 10·5° C. (18·1° F.) The two surface irrigation farms, South Norwood and Beddington, shewed a mean monthly range of 15·9° C. (28·7° F.) and 18·6° C. (33·6° F.) respectively. The Nottingham sewage has a high temperature throughout the year, which may possibly be due to some extent to the manufacturing refuse which enters the sewers, and also to the fact that the asphalted top of the outfall sewer for some miles is exposed to the direct rays of the sun.

It is well to bear in mind the fact that the evaporation and transpiration in summer is very great on all the farms, particularly so on the Aldershot Camp Farm; hence in reality a stronger sewage is being treated than that which arrives at the farm. This is borne out by the Aldershot Camp samples, which were distinctly stronger in June and July than in the spring. On the other hand, snow and rainfall tend to weaken the sewage in its course over and through the land, also tending to dilute the effluent and raising the level of the subsoil water.

With regard to Beddington and South Norwood a large amount of transpiration takes place, the greater portion of the land under irrigation being rye-grass. A medium sized plant of rye-grass taken from South Norwood farm in the spring gave a superficial leaf area of 40 square inches, and as the plants grow closely together an immense area is afforded for transpiration. The rye grass, and crops in general too, have a tendency to keep the temperature of the soil even, extremes of heat and cold being ameliorated thereby.

It may be noted in connection with the South Norwood farm, which rests on the London clay, that prolonged frosts penetrate much further into clay soils than in the case of light porous soils.

A daily record of the humidity was taken at South Norwood (two visits), Cambridge, Rugby, Altrincham, and Aldershot Camp, with a view to obtaining data as to the smell from sewage farms.

Broadly speaking, the degree of smell from sewaging operations was more perceptible in the presence of a high degree of humidity than when the atmosphere was comparatively dry. The diffusion of smell from sewage farms seems, however, to be largely influenced by other factors, such as barometric pressure and absence of wind.

NOTTINGHAM.

Mean Monthly Temperatures of Air, Sewage, and Effluent.

Month.	Farm.	Air.		Sewage.		Effluent.		Remarks.
1900 :		C.	F.	C.	F.	C.	F.	
October - -	Nottingham - -	12·4°	(54·3°)	17·7°	(63·9°)	11·9°	(53·4°)	Mean daily temperature for the month of October 1900.
November -	" - -	9·6°	(49·4°)	16·9°	(62·4°)	10·7°	(51·3°)	
December -	" - -	6·4°	(43·5°)	14·5°	(58·2°)	9·1°	(48·5°)	
1901 :								
January -	" - -	4·0°	(39·2°)	12·5°	(54·6°)	6·6°	(43·9°)	
February -	" - -	1·4°	(34·6°)	13·0°	(55·4°)	6·2°	(43·2°)	
March - -	" - -	5·6°	(42·2°)	13·2°	(55·8°)	6·4°	(43·5°)	
April - -	" - -	12·5°	(52·6°)	14·1°	(57·4°)	6·9°	(44·5°)	
May - -	" - -	15·7°	(60·3°)	16·5°	(61·7°)	8·7°	(47·8°)	
June - -	" - -	17·2°	(63·0°)	18·2°	(64·9°)	9·6°	(49·4°)	
July - -	" - -	20·8°	(69·5°)	19·0°	(66·2.)	13·1°	(55·7°)	
August - -	" - -	17·6°	(63·8°)	18·7°	(65·8°)	12·7°	(55·0°)	
September -	" - -	15·4°	(59·8°)	19·0°	(66·3°)	13·4°	(56·1°)	
Averages for the year - - -		11·4°	(52·6°)	15·8°	(60·5°)	9·6°	(49·4°)	

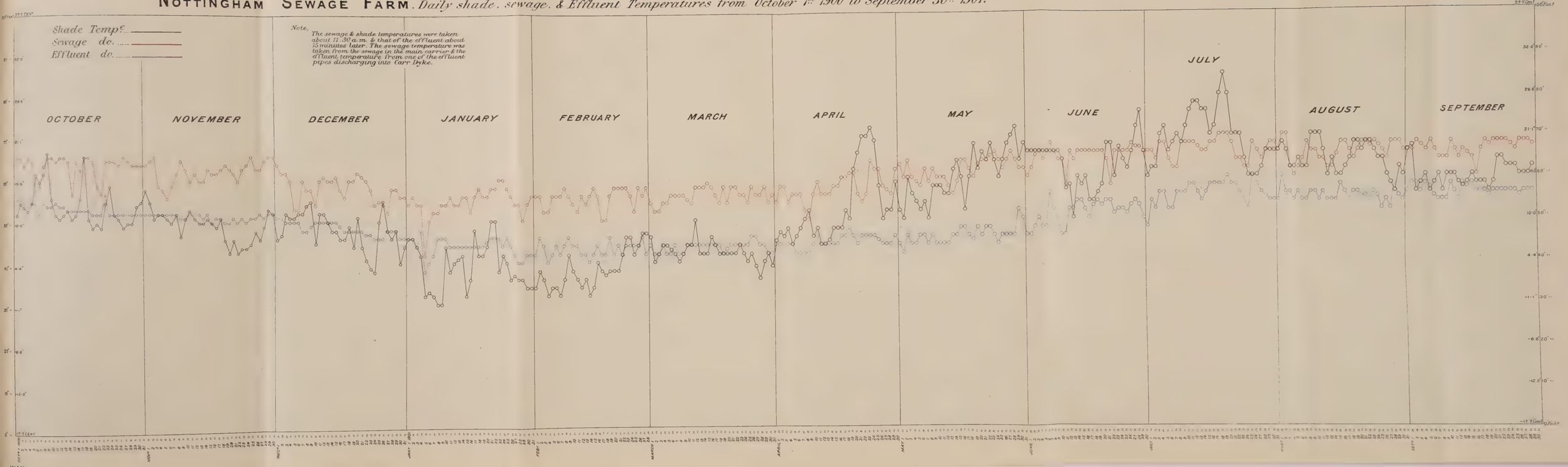
ALDERSHOT CAMP SEWAGE FARM.

Mean Monthly Temperatures of Air, Sewage, and Effluent.

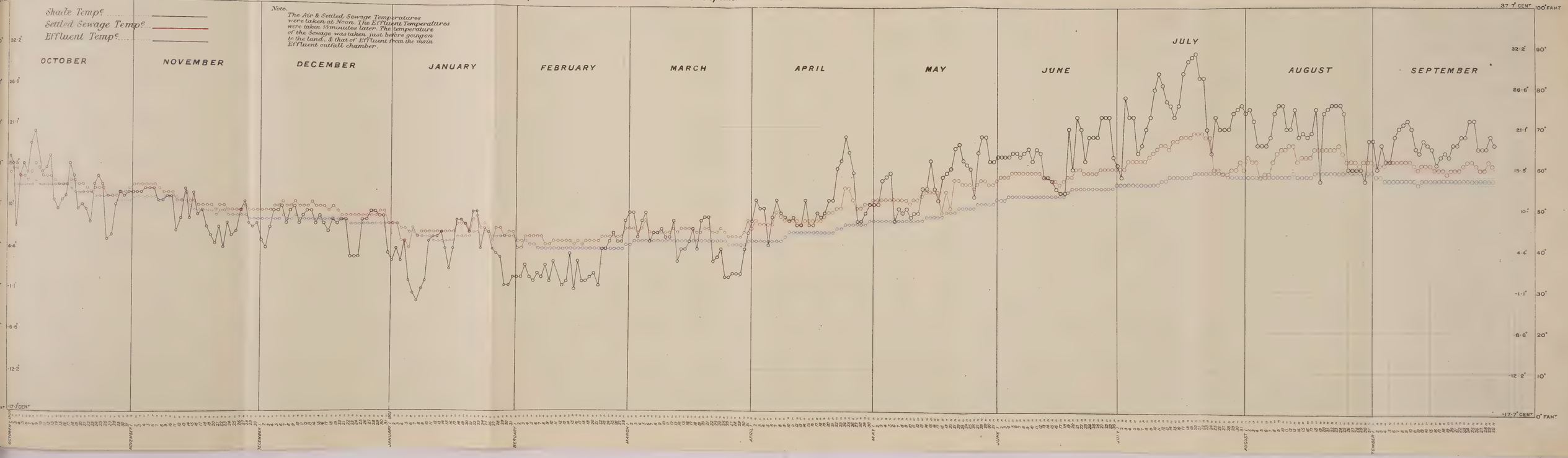
Month.	Air.		Sewage.		Effluent.		Remarks.
1900 :	C.	F.	C.	F.	C.	F.	
October - - -	12·4°	(54·3°)	13·0°	(55·5°)	12·0°	(53·7°)	
November - -	9·1°	(48·4°)	10·7°	(51·4°)	9·9°	(49·8°)	
December - -	7·7°	(46·0°)	9·5°	(49·1°)	8·1°	(46·7°)	
1910 :							
January - -	4·0°	(39·2°)	6·8°	(44·3°)	6·2°	(43·3°)	
February - -	2·0°	(35·7°)	5·6°	(42·2°)	4·6°	(40·3°)	
March - - -	5·5°	(41·9°)	6·9°	(44·4°)	5·4°	(41·8°)	
April - - -	10·4°	(50·8°)	9·0°	(48·3°)	6·6°	(44·0°)	
May - - -	13·8°	(56·9°)	12·0°	(53·6°)	9·1°	(48·4°)	
June - - -	17·7	(64·0°)	14·6°	(58·3°)	12·0°	(53·6°)	
July - - -	23·7°	(74·8°)	17·6°	(63·8°)	14·1°	(57·4°)	
August - - -	20·7°	(69·3°)	17·2°	(63·0°)	14·6°	(58·4°)	
September - -	19·0°	(66·2°)	16·0°	(60·9°)	19·9°	(57·1°)	
Averages for the Year - -	12·1°	(53·9°)	11·0°	(51·9°)	9·7°	(49·5°)	

Temperatures

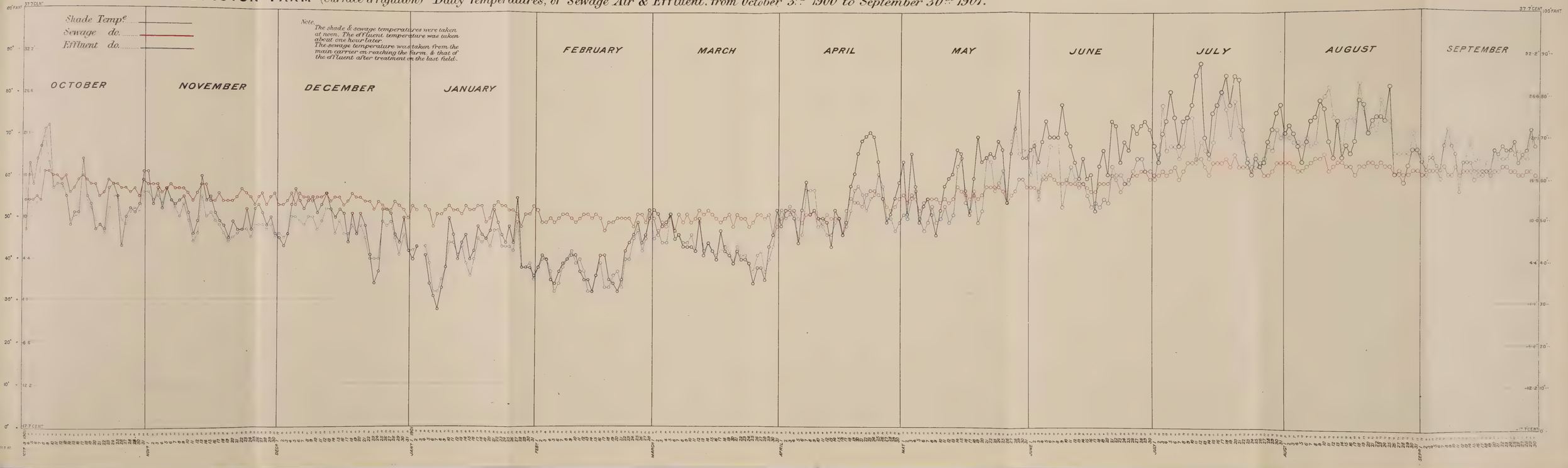
NOTTINGHAM SEWAGE FARM. *Daily shade, sewage, & Effluent Temperatures from October 1st 1900 to September 30th 1901.*



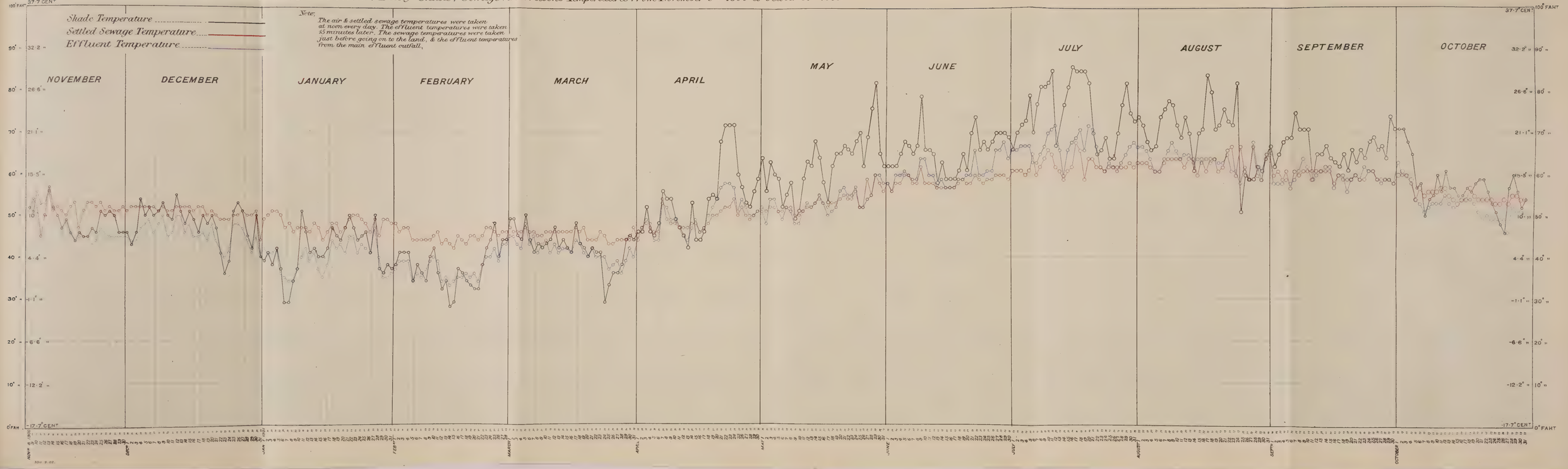
ALDERSHOT CAMP FARM. *Daily Shade, Sewage, & Effluent Temperatures from October 1st 1900 to September 30th 1901.*



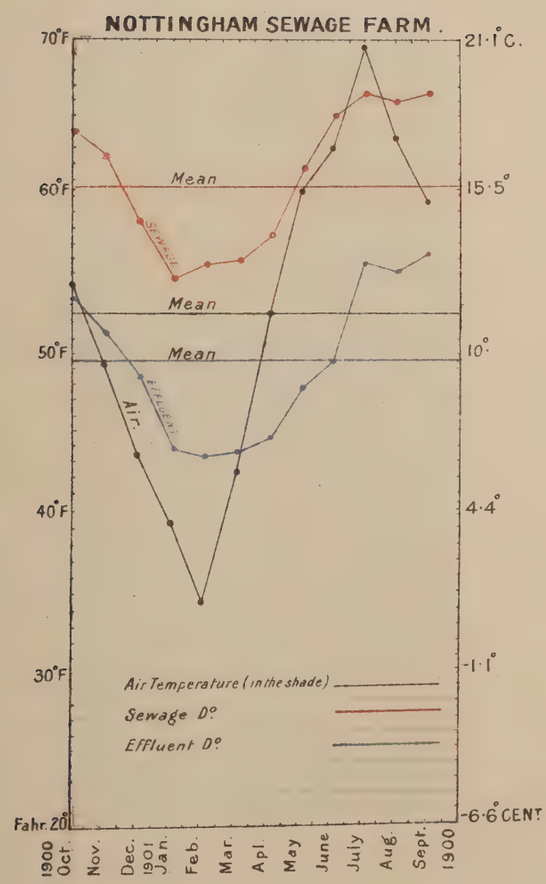
BEDDINGTON FARM *(Surface irrigation) Daily Temperatures, of Sewage Air & Effluent, from October 3rd 1900 to September 30th 1901.*

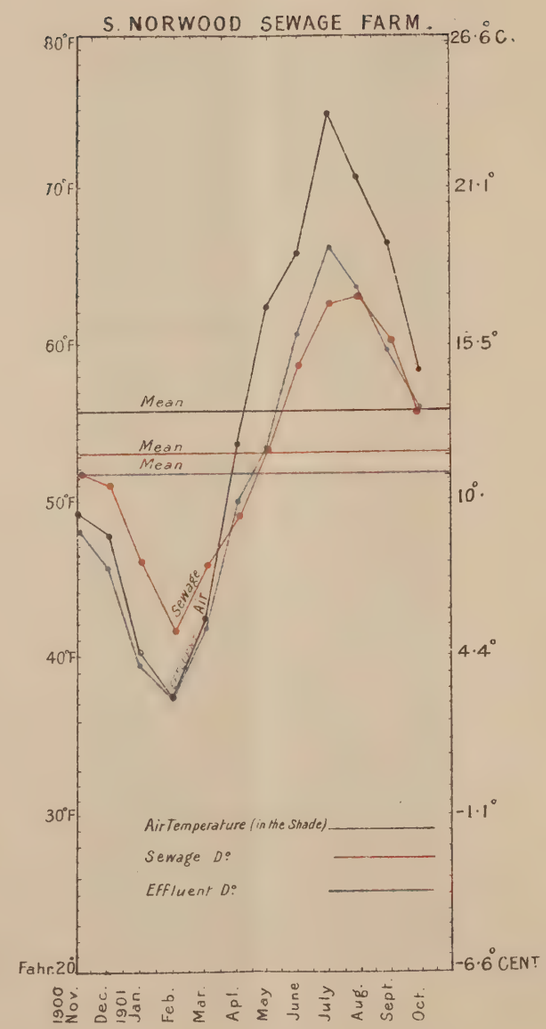


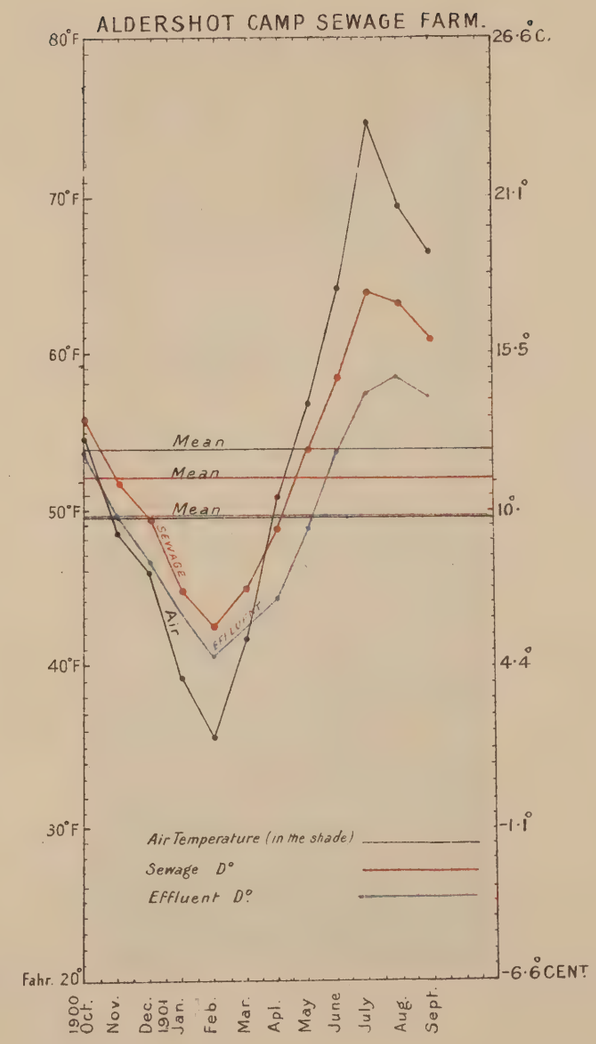
S. Norwood Sewage Farm. *Daily Shade, Sewage, & Effluent Temperatures from November 8th 1900 to October 31st 1901.*

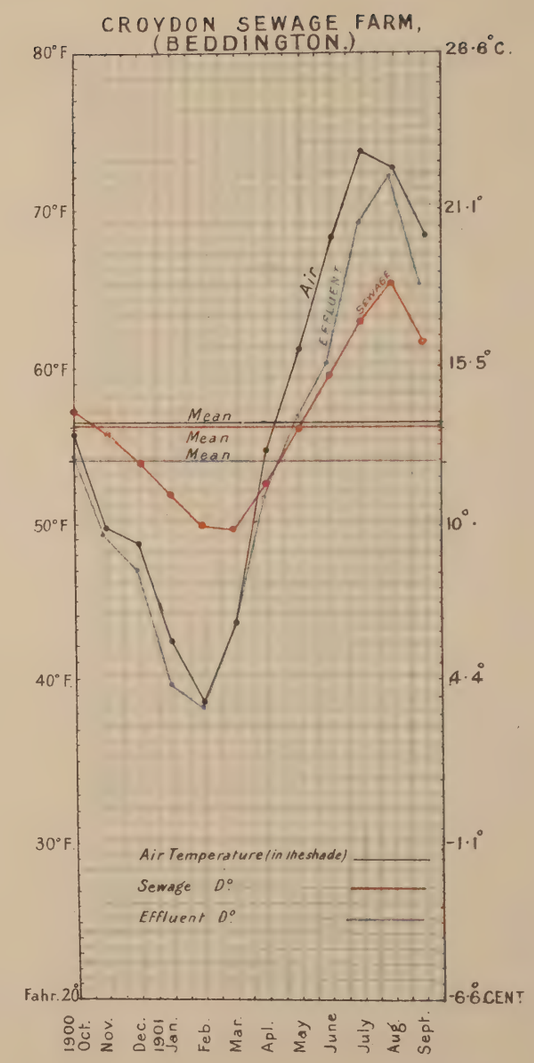


Temperatures.









NOTE. *The horizontal black red & blue lines give the mean Temperatures for the year of the air sewage & effluent respectively.*

3111. 11 02.

CROYDON SEWAGE FARM—(Beddington.)

Mean Monthly Temperatures of Air, Sewage, and Effluent.

Month.	Air.		Sewage.		Effluent.		Remarks.
1900:	C.	F.	C.	F.	C.	F.	
October - - -	13·1°	(55·6°)	14·1°	(57·4°)	12·2°	(54·0°)	Temperatures are omitted for the 1st and 2nd October.
November - - -	9·8°	(49·8°)	13·2°	(55·8°)	9·6°	(49·3°)	
December - - -	9·4°	(48·8°)	12·1°	(53·9°)	8·3°	(47·0°)	
1901:							
January - - -	5·7°	(42·3°)	11·0°	(51·9°)	4·2°	(39·7°)	Temperatures are omitted on 3rd January.
February - - -	3·8°	(38·9°)	9·9°	(49·9°)	3·6°	(38·5°)	
March - - -	6·3°	(43·4°)	9·7°	(49·6°)	6·2°	(43·2°)	
April - - - -	12·7°	(54·9°)	11·2°	(52·2°)	10·9°	(51·7°)	
May - - - -	16·1°	(61·1°)	13·3°	(56·0°)	13·7°	(56·7°)	
June - - - -	19·8°	(67·7°)	15·1°	(59·3°)	15·6°	(60·2°)	
July - - - -	23·1°	(73·7°)	17·1°	(62·8°)	15·1°	(69·3°)	
August - - -	22·6°	(72·7°)	18·3°	(65·1°)	22·2°	(72·1°)	
September - - -	20·2°	(68·5°)	16·4°	(61·6°)	18·4°	(65·2°)	
Averages for the Year - -	13·5°	(56·4°)	13·4°	(56·2°)	12·1°	(53·9°)	

SOUTH NORWOOD SEWAGE FARM.

Mean Monthly Temperatures of Air, Sewage, and Effluent.

Month.	Air.		Sewage.		Effluent.		Remarks.
1900:	C.	F.	C.	F.	C.	F.	
November - - -	9·5°	(49·2°)	10·7°	(51·4°)	7·9°	(46·3°)	Temperatures were not taken from the 1st to the 7th of November.
December - - -	8·4°	(47·9°)	10·4°	(50·8°)	7·5°	(45·6°)	
1901:							
January - - -	5·1°	(41·3°)	7·7°	(45·9°)	3·9°	(39·1°)	
February - - -	3·0°	(37·4°)	5·1°	(41·3°)	2·9°	(37·3°)	
March - - -	5·7°	(42·3°)	7·4°	(45·4°)	5·3°	(41·6°)	
April - - - -	11·8°	(53·3°)	9·4°	(48·8°)	9·9°	(49·9°)	
May - - - -	16·8°	(62·3°)	11·6°	(53·0°)	11·7°	(53·1°)	
June - - - -	18·7°	(65·7°)	14·6°	(58·4°)	15.8°	(60·6°)	
July - - - -	23·7°	(74·8°)	16·8°	(62·3°)	18·8°	(66·0°)	
August - - -	21·6°	(70·9°)	17·1°	(62·8°)	17·5°	(63·5°)	
September - - -	19·1°	(66·5°)	15·5°	(60·0°)	15·4°	(59·8°)	
October - - -	14·0°	(57·2°)	12·9°	(55·3°)	13·2°	(55·9°)	
Averages for the Year - -	13·1°	(55·7°)	11·6°	(52·9°)	10·8°	(51·5°)	

APPENDIX B.

SOIL AND SUBSOIL SAMPLES.

Samples of surface soil* and subsoil were taken from the following eight farms, viz. :—Altrincham, Aldershot Camp, Beddington, Cambridge, Leicester, Nottingham, Rugby and South Norwood.

All samples were taken from within the irrigable area. The samples were drawn in the following manner, six tins being used for the surface soil, and six for the subsoil.

Each of the six tins in the case of the surface soil was filled with three approximately equal portions of soil, drawn from different parts of fields having the most typical soil, but which were not actually under sewage at the time of sampling. The soil was taken both from the actual surface of the soil and also at the same spot about half way down the full depth of surface soil.

Thus, the six tins combined contained eighteen samples of surface soil.

The subsoil samples were drawn in a similar manner to the surface soils, with the exception that each of the six tins was filled with two portions of subsoil instead of three, making twelve samples in all.

The subsoil samples were taken at the depths of about twelve and eighteen inches from the base of the surface soil. At Nottingham, owing to the laying of the new syphon carrier, a section of the soil and subsoil was exposed for many hundred yards. At Beddington and Cambridge there were also exceptional opportunities of obtaining accurate sets of samples, excavations at Beddington, and draining operations at Cambridge being in progress. In the case of Leicester sewage farm the subsoil sample was taken from the yellow clay overlying the boulder clay.

TWENTY-FOUR HOURS SEWAGE SAMPLES.

These samples were taken at the following farms :—Leicester, South Norwood, Beddington, Aldershot Camp, Nottingham, Rugby, and Cambridge.

At Beddington and South Norwood these samples were taken continuously for a period of seven days. At the remainder of the farms they were taken for three days only.

The sewage in every case was taken in the same state in which it is applied to the land ; that is to say, after any screening, settling, etc., had taken place.

The method employed in sampling was to take an equal quantity of sewage hourly for 24 hours, each hourly sample being placed in a covered vessel, the contents at the expiration of each 24 hours being thoroughly mixed with a glass stirring rod, and one or more samples drawn from the mixture.

The following table shows the various processes the sewage was subjected to before being sampled :—

Aldershot Camp - -	Screening and settling tanks.
Beddington - - -	Screening.
South Norwood - -	Screening and settling tanks.
Rugby - - - -	Screening and settling tanks.
Nottingham - - -	Screening (partial).
Leicester - - - -	Screening and settling tanks.
Cambridge - - -	Screening and settling tanks.

In order to avoid disturbing any sediment in the carriers from which the samples were drawn a glazed vessel was fastened to a rod about six inches from the bottom, the vessel being dipped into the sewage until the point of the rod rested on the carrier invert, withdrawn, and carefully emptied into the covered vessel.

* By "surface soil" is meant the top layer of the subsoil (or weathered portion of the stratum immediately underlying the subsoil) ; such surface will have been modified by rainfall temperature, crops, sewaging, worms, etc.

Rainfall interfered considerably with the samples obtained from Beddington, the whole of the storm water coming to the farm, with the exception of that carried off by the separate system. At Cambridge and Nottingham also rain fell, but not in any great quantity.

As the samples were drawn hourly in equal quantities, and not according to the rate of flow, they cannot be regarded as true average samples, although in the case of a large amount of subsoil leakage to the sewers, the sewage being taken in equal quantities, would not affect the samples so much, the sewage flow being somewhat equalised by subsoil water, which enters the sewers with greater facility when the sewage flow proper is at its lowest. Hence, the greatest dry weather flow generally taking place when the sewage is strongest, the above samples may be looked upon in general as being rather weaker than the true average sewage for the 24 hours.

APPENDIX C.

SEWERAGE SYSTEMS.

The separation of rain water from sewage to the fullest extent practicable renders the efficient disposal of the sewage at the farm a matter of far less difficulty than when the farm manager does not know whether during the next hour or so he may be having five or ten times the normal quantity to deal with, temporarily throwing the working of the farm out of gear.

For purposes of discussion sewerage systems may be broadly divided into two classes—

(1) The combined system, in which all roof and surface water from streets, etc., is admitted to the sewers.

(2) The partially separate system, in which water from the streets, pavements, and front roofs of houses is carried off direct to the watercourses, streams, etc., by a separate set of sewers and is not in any way treated.

The separate system proper is rarely carried out in its entirety.

For the entirely separate system three sets of pipes are required for water-logged subsoils, viz., sewage, subsoil water, and surface water pipes.

In what follows, therefore, when the "separate" system is spoken of, it is intended to refer to the "partially separate" system.

Both the separate and combined systems have many advocates, and it may be well to deal in detail with the several features peculiar to each system.

The tendency of most towns at the present day is to provide the separate system in all new streets, and also under certain circumstances when replacing old lengths of defective sewers.

One advantage accruing from the separate system is that the fluctuations in the sewage flow at the outfall works, which occur in times of storm with the combined system, are greatly lessened, the extent varying according to the degree of separation carried out. It must however be remembered that even with the separate system it sometimes happens that the rate of flow of the sewage proper may be increased several times for some hours, and that storm overflows cannot be dispensed with.

In addition the amount of sludge received on the farm is materially reduced, owing to the street gullies taking off the road detritus. These gullies during heavy rainfall rapidly fill up with detritus, etc., from street scourings, and when this occurs the grit is washed directly to the sewers in the combined system.

On the other hand street and backyard scourings are very frequently, for a time at all events, almost as foul as the sewage itself, and particularly is this the case in the poorer and densely populated districts of a large town, where the streets are narrow and the sanitary arrangements of a primitive character.

In such places there is a tendency to empty slops and other objectionable matter into the streets, with the result that it finds its way to the separate system through the street gullies. This fouling of the streets is particularly noticeable in districts where tub closets and privies are in use.

In connection with the above it may be well to point out that if two sets of drains exist at the back of houses, there is danger of the sewage drain being connected to the rain water sewer, either purposely or otherwise, in the event of anything going wrong with the former: This however should not occur with proper supervision.

It is often urged in favour of the combined system that the rainfall admitted to the sewers materially assists in scouring out the sewers, and there is no doubt that to some extent this is the case, but it is chiefly in dry, hot weather, and in the absence of rainfall that the sewers require flushing most of all, and this can only be assured regularly by means of flushing chambers at the heads of the various lines of sewers.

Another point with regard to the combined system is that it would be practically impossible in most towns having a high rainfall to construct sewers at any reasonable cost, capable of carrying off all the rainfall, apart from the question of treating it, and even supposing it to be feasible, the flow in sewers of such a size during dry weather would have an exceedingly low velocity, and an enormous amount of water would be requisite to flush them satisfactorily.

Where the sewage is treated by precipitation, and large volumes of rain-water are admitted to the sewer, it is probable that this would necessitate an increased dose of chemicals, and consequently increased cost of treatment. On the ground of cost, too, it is also desirable in pumping schemes to reduce the volume to be pumped as far as possible.

Regarding the relative cost of the combined and separate systems, much must necessarily depend upon local conditions, *e.g.*, whether facilities exist for discharging the storm water without long and therefore large sewers. The latter system, taking everything into consideration, is seemingly not so expensive as it appears at first sight, although insistence on the separate system of course increases the liability of frontagers upon private streets. In the separate system, for instance, smaller sewers can be laid to take the sewage proper, and also a small proportion of rain water, and in many cases old sewers exist which can be utilized for carrying off the balance of the rain water.

In cases where new rain water sewers have to be constructed, they will not as a rule be so expensive as the foul water sewers, from the fact that basements of houses have not to be drained, and therefore the separate system pipes do not need to be laid so deep. Moreover, they can often have many outfalls, as it is not essential that all the surface water (like the sewage) should be discharged at one point. Flushing of rain water sewers is required, as in the case of the foul water sewers, and in addition the cost of maintenance and supervision have to be taken into account.

From the foregoing it will be seen that it may be advantageous from a practical point of view to provide the separate system either wholly or in part, according to the requirements of the case, but that this must be determined largely by what the nature of the street washings is likely to be, and whether the liquid is going to be discharged into a drinking or non-drinking water stream.

In the case of drinking water streams, at all events, the question turns upon whether the liquid derived from streets, etc., is—at certain times—to be regarded as in any degree less harmful and polluting than a dilute sewage.

In other words, is it better (1) to receive the rainfall into the foul water sewers and have a system of storm overflows frequently coming into operation, or (2) to divert as much as possible of the rainfall into the separate system sewers and have storm overflows on the line of sewers proper, which shall only work under exceptional circumstances, such as when the sewers are running full or under pressure.

This appears to be a question to be decided from the chemical and bacteriological standpoint, having due regard to the fact that, (1) in the majority of cases storm overflows will be a necessity with both separate and combined systems if flooding of streets is to be avoided, (2) that both storm overflows and separate system pipes frequently discharge into the same stream or river which receives the effluent, and (3) that if large volumes of sewage and storm water are dealt with on land already saturated with rainfall, the result will be that the volume of the effluent from the farm will be very greatly increased.

STORM OVERFLOWS.

The question of storm overflows is an important one. It is probably impracticable that sewers should be constructed to carry off all the rainfall which must reach them under certain conditions — and it follows that safety valves in the shape of storm overflows must be provided to carry off at a certain point or points sewage and storm water in excess of that which the sewers are required to deal with.

Even with the partially separate system it must be remembered that short showers, if intense, will increase the normal rate of flow many times over for the time being. This can be easily understood, when it is recollected that during rainfall the back roofs and yards in a town, which are usually constructed of more or less impervious material, will contribute to the sewers proper.

Again, the question of how much surface water will get to the sewers depends in great part, as previously stated, on the rate of fall or intensity of the rainfall. For instance, a rainfall of ·25 inch in 15 minutes may cause a large increase in the sewage flow for the time being, whereas the same amount (·25 inch) spread over several hours may scarcely affect the flow appreciably.

Although the total proportion of rainfall to the sewage for the year may appear small, this can by no means be accepted as proof that the sewers have been sufficient to deal at all times with the flow of storm water and sewage without bringing the storm overflows into operation. For example, it sometimes happens that for some hours (even in partially separate systems) the rain water reaching the sewers may increase the rate of flow by as much as ten times.

The infiltration of subsoil water to sewers is frequently a disturbing factor. Its immediate effect is to equalize the hourly variations in the sewage flow for the reason that during the night and early morning the flow of sewage *per se* is in most cases at its lowest. Hence at this period the pressure of the subsoil water from without is more than ordinarily greater than the pressure of the sewage from within. Of course the converse (*i.e.*, pollution of the soil with sewage) may occur when the sewage is under pressure.

The nature of the strata in which the sewers are laid affects the quantity of subsoil water likely to gain access to the sewers, *i.e.*, a maximum amount would be likely to occur in a water-bearing gravel, and a minimum in a stiff clay subsoil; there is, however, a tendency of subsoil water in a clay soil to flow along the pipe line as the line of least resistance.

In some districts where subsoil leakage occurs, a considerable after effect of rainfall is felt, affecting the volume of liquid received at the outfall for some days after the rainfall.

As a rule it will be found that in sewerage schemes where pumping is employed, the sewers are better laid, and there is less infiltration of subsoil water than in gravitation schemes, and consequently the volume of sewage to be pumped is reduced as far as possible. In a new sewerage scheme an allowance for leakage to the sewers of one cubic foot of subsoil water per mile per minute for all sewers is generally considered the limit.

At what point a storm overflow should come into operation seems to be a matter to be determined by local circumstances, such as the nature of the sewage, volume of subsoil water gaining access to the sewers, and volume of the river or stream into which the storm overflows discharge.

Assuming 30 gallons per head as a fair average, the sewage in some towns is, by reason of subsoil water already diluted to two or even three times the normal 30 gallons, and therefore such cases as these would seem to stand on a different basis so far as storm water is concerned.

Taking the case of two non-manufacturing towns of the same population, but one (A) producing 30 gallons of sewage per head per day, and the other (B) owing to subsoil water, 60 gallons of sewage.

Assuming that both of these towns have storm overflows working at six times the mean dry weather flow, the overflow from (A) will discharge

at 180 gallons per head, whereas (B) will have to treat 360 gallons per head before an overflow is permitted, although presumably the quantity of polluting matter produced by individuals in either (A) or (B) is to all intents and purposes the same.

It follows that in such a case, (B) will be put to considerably more expense, both in laying down a sewerage system, and also in provision of land, to deal with such a large volume of sewage which is weaker in nitrogenous matter than the liquid overflowing untreated in the case of (A).

The usual practice followed in the arrangement of storm overflows is to divide the town sewered into separate drainage areas as far as possible, each area having one or more storm overflow in addition to the main storm overflow on the outfall sewer.

The object of this is to carry off the storm water as soon as possible, and thus relieve the branch sewers; otherwise an immense volume of water would have to be dealt with by the overflows on the main outfall sewers, gorging the sewers and causing the sewage to rise up several feet in the manholes. The question of how much storm water is to be dealt with is, from the point of view of expense, of vital importance where the sewage has to be pumped.

The ordinary pumping of the dry weather flow is an expensive item in itself, but when to this is added large volumes of storm water, it becomes a very serious matter to a small town, both as regards initial outlay for pumping plant, and also the increased cost of pumping.

The fact must not be lost sight of that during storms the manager of the sewage farm often has, in the case of storm overflow working at a large number of dilutions, to dispose of large volumes of sewage and storm water, when the land of the farm itself is already saturated by the rainfall, and usually at times when the crops are least in need of excessive moisture. Moreover the volume of effluent from the farm will be largely increased.

With regard to the amount of storm water likely to reach the sewage farm during rainfall, it may be observed that there is no invariable relation between rainfall and increase of flow at the sewer outfall, this depending upon a variety of circumstances, amongst other things, the slope of the ground, size, length, and gradients of the branch and outfall sewers. It does not necessarily follow therefore that because a rainfall of ·5 inch from noon until 3 p.m. on one particular day gives, say, six times the ordinary rate of flow for that period, that the same amount can be relied upon on another occasion, with a similar rainfall of like intensity. A saturated surface and a high degree of humidity give a maximum "off-flow," and, conversely, a dry surface with a high temperature and drying wind will give the reverse, with an infinite number of gradations between the extremes. Frequently an immense "off-flow" is caused after a severe frost and snow, by a sudden thaw accompanied by rain, the frozen state of the ground rendering it practically impervious.

From the foregoing it will be seen that it is impossible to arrange a fixed storm overflow so that at any period of the 24 hours the overflow will take place when the sewage is diluted to an equal extent; because the flow of sewage during the 24 hours fluctuates to a marked extent; causing an overflow during the period of maximum flow at less than the desired dilution, and possibly not acting during the period of minimum flow when the desired dilution is more than exceeded.

It is well to bear in mind the fact that—in the case of the ordinary storm overflow cill—if, say, 6 inches of liquid are passing over the cill, it means an additional head of 6 inches acting on the outfall sewer. In the case of pumping schemes the amount received at the farm can of course be regulated by keeping the pumps at a constant known speed, in which case all the overplus must go off by the storm overflows.

SETTLING TANKS.

The question of settling tanks in connection with the land treatment of sewage is an important one.

The primary object of settling—(or sedimentation)—tanks, is to remove the bulk of the suspended solids in the sewage before going on to the land, by subsidence, either (1) mechanical, or (2) with the aid of chemical precipi-

tants. In the latter case, the quantity of sludge produced will be largely increased.

The different forms of settling tanks in use are almost numberless; they are, however, all worked either on the continuous or quiescent system.

In many pumping schemes a portion of the outfall sewer is enlarged to act as a storage tank, and so save night and Sunday pumping.

This appears to be an advantage in many respects, and the hourly variations in flow tend to become equalised by this method, a matter of considerable import if there is much manufacturing refuse. The chief objection to this method is the rapid silting up of the sewer which takes place.

With the continuous system, the sewage is constantly running through the tanks, whereas in the quiescent method, a tank is filled with sewage, allowed to rest for a certain period, and the clear portion of the liquid drawn off, usually by means of floating arms. Unless the effluent is pumped from the tanks, the latter system requires several feet of fall.

The efficiency of settling tanks varies, up to a certain point, almost proportionately to the rate of flow through them. It should be stated, however, that, beyond that point, the extra amount of sedimentation effected by any additional stay in the tanks is exceedingly small.

It follows from this that during the night and early morning, when the dry weather flow is usually least, the stay in the tank will be considerably longer than at midday, when the sewage is very much stronger.

As regards cost, the continuous system is the more economical of the two methods, both as regards initial cost and also labour in attendance, and will alone be considered here, as a preliminary to land treatment.

On the design of the settling tanks, apart from the question of effective sedimentation, depends in great measure the question whether the removal of sludge is going to be a tedious and expensive operation or the reverse. Tanks which are difficult to clean out are very seldom cleaned as often as is necessary, and this omission frequently causes a nuisance in their immediate vicinity; the design should be such as to facilitate cleaning with a minimum of labour.

Another fault that is commonly met with is that insufficient slope is given to tank floors, the sludge in consequence not sliding properly to the sludge sump, and necessitating much manual labour, and consequent expense.

Of rectangular tanks the best form seems to be that in which the tank bottom slopes downwards from the outlet cill to the inlet of the sewage.

With this form the bulk of the sludge has a tendency to remain at the deeper (or inlet) end of the tank, and can here be withdrawn by opening a valve without greatly disturbing the surface liquid.

The greater the length of the overflow cill, the more even will be the flow of liquid over the cill, and, consequently, the more even the sedimentation; in connection with this point diagrams are given (Aldershot Camp, Add. B. VII.; Cambridge, Add. B. III.; Leicester, Add. B.IV.) showing the rapid fluctuations which take place in the flow of liquid over tank cills

The sludge resulting can, if the levels permit, be run off either (1) directly into a sludge bed, (2) into the carriers and thence to any part of the land desired, or—if this is impracticable—(3) run into a sludge well, and raised by means of a chain pump or other method to the required level.

The capacity of settling tanks for the majority of sewage farms would seem to be largely governed by local circumstances, such as the nature of the soil by the agency of which the sewage is to be purified.

For instance, the suspended solids in a tank effluent going on to a heavy clay soil would naturally require to be removed as far as possible, whereas with a sandy soil of poor quality, there would be no object in removing any but the grosser solids, unless the sludge can be regularly disposed of at a profit, which is seldom the case.

The more effectually a sewage is settled, the larger the amount of sludge produced, which in the case of farms with light soils is usually dug or ploughed into the land by labour.

The layer of sludge deposited by the sewage in course of irrigation methods is far more evenly distributed than by manual labour, and therefore in such cases there would seem to be no advantage, but rather a distinct

disadvantage, in having tanks of a high capacity. At the same time, solids must not go on to the land in sufficient quantity to lie on the surface for any length of time and create a nuisance.

The general rule for the capacity of settling tanks is based on the fact that 8 per cent. of the total dry weather flow may be received at the farm in one hour.

Two hours is the usual time required for efficient sedimentation, therefore a tank to allow a settlement of two hours must have a capacity equal to 16 per cent. of the dry weather flow.

This tank cannot be used during cleaning operations, and so a second similar tank will be required, bringing the capacity up to 32 per cent. A third tank for use during storms brings the total tank capacity up to 48 per cent. (or about 50 per cent.) of the dry weather flow.

It is usually convenient to subdivide the tanks, as by this means a larger portion of the tanks continue working when cleaning out takes place.

In the case of upward straining tanks (*i.e.*, where the sewage rises through a layer of filtering material, resting on a false bottom, and thence over the tank cill), the tank capacity will not, of course, need to be so high as in the case of the ordinary form of settling tank.

The above rule would appear to answer well in the case of heavy soils, but as there are farms which without tanks satisfactorily deal with the whole of the suspended matter, in the ordinary course of sewaging operations, it is clear that this rule is not universally applicable.

The degree to which suspended matter should be removed from a tank effluent seems to be one which largely depends on (1) the condition in which the sewage arrives at the farm, (2) the amount of suspended matter the land can effectually deal with, (3) the facilities for regular disposal of the sludge, if removed from the tanks.

UNDERDRAINS AND CARRIERS.

The cost of laying out land for sewage treatment varies entirely according to local circumstances, such as the configuration of the land, number of carriers and underdrains, nature of subsoil, distance materials have to be carted, etc. As a rule, with a porous soil and subsoil, it seems advisable in the first place to put in as few underdrains as possible, and where practicable to lay these under the farm roads. It is usually easy to add additional drains should these be found necessary, whilst the removal of existing drains is an unsatisfactory process. In cases where a large amount of subsoil water exists, an underdrainage system is of advantage in this respect, namely, that it lowers the subsoil water, and thus gives a greater depth of material in which to purify the sewage. As a general rule all land (excepting clay) should be drained where the subsoil water lies four feet below the surface of the ground. If the water table lies on an average at, say, a depth of four feet, and this can be reduced a couple of feet by means of an efficient underdrainage, two additional feet of filtering medium are obtained. Deep and well-drained ditches tend to reduce the subsoil water level. It may be noted that in the case of the Nottingham sewage farm, where the underdrains average six feet in depth, this means (taking the average depth of drains on most farms at three feet) that the farm has in reality double the area of a farm of the same size with drains only three feet deep, although of course without the top soil in the one case.

Underdrains undoubtedly assist in aerating the soil. Insome cases air-vents are placed at the end of the main drains; in such cases, unless the mouth of the pipe is carried at least a foot above the surface level of the ground, the sewage during storms flows direct through the vents to the underdrains unpurified. Where such vents are in use iron gratings fitted to the mouths of the pipes are advisable to prevent stones, etc., gaining access to the underdrains.

For ordinary purposes of draining the agricltural butt tiles answer well for feeder drains; in special cases, howeveu such as in peat y soils and land liable to subsidence through coal workings, etc., second quality

socketted pipes with open joints seem advisable, although where these are employed the filtration of effluent to the pipes is through the joint of the pipe only, and not through the whole of the surface in addition as in the case of the unglazed pipes. The joints in the latter, too, are more numerous owing to their shorter lengths. In the case of socketted pipes a direct waterway is apt to be worn by the effluent. The question of the filling above the underdrains is a most important one. The filling in and ramming should be very carefully carried out, leaving no loose place allowing the effluent direct access to the drain.

The soil should be filled in as taken out, so that the surface soil remains on the top. Turfing is sometimes laid over the drain joints before being filled in; this appears to answer in some soils, but in others there appears to be considerable risk of the turf decaying and causing the filling immediately above it to subside. Underdrains appear to "draw" best when laid either at right angles or diagonally to the slope of the land.

Drains laid parallel have this advantage, namely, that in sewage operations the sewage can be confined to any particular strip of land, and thus in the event of anything going wrong with the drains, the sewage can be shut off from each drain until the one causing the mischief is reached. Where the face of the land is uneven, it is frequently necessary to lay the drains herring-bone fashion.

The main drains or master drains, to which the subsidiary or feeder drains are connected up should be socketted stoneware pipes. Heavy clay subsoils should only be underdrained on one condition, namely, that (as at Leicester) the drain effluent can be picked up and re-treated on the surface.

The draining of dense clay soils only tends to aggravate the deep cracks which always occur in hot weather, and as a consequence the sewage runs direct to the drains with hardly any treatment. Turf overlying a heavy clay tends to ameliorate this tendency to crack. It is unusual on many sewage farms to find two fields that give similar results under similar conditions, and it is frequently necessary in the case of a surface irrigation farm to put in a few underdrains to assist land which is liable to become waterlogged, and which would otherwise take days to dry off. The distances apart of feeder and main drains depend entirely on the nature of the soil and subsoil and the quantity of water to be dealt with. The surface soil acts as a regulator to the rate of filtration per square yard, and in the case of a loose, porous soil, overlying loose gravel and shingle, the drains will usually have to be laid much closer than in the case of a fine soil overlying sand, where the percolation as a rule is exceedingly slow.

The distribution of the sewage over the land cannot be too carefully attended to. On comparing the system of distribution obtaining on the majority of artificial filters with the frequently crude methods by which sewage is poured on to the land, it seems probable that if the sewage were distributed on land even approximately as carefully as on artificial filters, greatly improved results would accrue as regards the effluent.

A proper ratio between the sewage flow, carriers, and underdrains should be observed, having due regard to the maximum amount of storm water to be dealt with at the farm. The flow in carriers may vary greatly thoughout the 24 hours (*see* Croydon, Beddington—Addendum B. III.) with the normal flow of sewage. The size and distance apart of the underdrains will be governed principally by the porosity or otherwise of the soil and subsoil, etc.

It should be borne in mind that when there are no settling tanks, or where the capacity of the tanks is not sufficient, the carriers themselves act largely as settling tanks.

This fact is especially noticeable in the case of the Nottingham sewage farm, where the carriers act as settling tanks, and probably the comparative absence of sludge on the farm is in part due to the fact that a certain amount of the sludge is digested in the carriers. The layer of sludge on a carrier invert with a slow velocity is not disturbed appreciably; further, the capacity of carriers on a sewage farm sometimes amounts to a large percentage of the dry weather flow.

In cases where the land receives the sewage direct from the carriers it also acts as a settling tank on a large scale.

Open sewage carriers where practicable seem preferable to piped carriers, the latter being very difficult to clean. They also appear to encourage sewage weed growths.

If piped carriers are laid at a steep gradient and eyelets are used with stoppers for sewage outlets, the sewage has to be held up in the carrier to enable the higher portions of the land to be sewaged, and when the lower part of the land is sewaged, all the silt (particularly in storms) is washed out on to the land where it can least do with it.

To distribute sewage efficiently on a porous soil and subsoil far more subsidiary carriers are needed than for an impervious soil, and this fact is accentuated in cases where the land is laid out in large plots. The smaller the plots, as a rule, the easier the distribution of the sewage becomes.

On the other hand a multiplicity of permanent carriers interferes with ploughing and cropping operations, and in consequence the land is not so frequently ploughed and cleaned as would otherwise be the case.

In the case of rye grass as a principal crop, if the plough cuts for bringing on the sewage can conveniently be made a constant distance apart, a considerable time is saved in measuring up, when the crop is gathered by piece work.

Earthen channels or carriers are, as a rule objectionable, from the fact that each cleaning out has a tendency to deepen them. They also encourage vegetation, and rats, moles, etc., frequently cause the sides to fall in. Where used they should be maintained at their proper levels.

Carriers should be frequently cleaned out, and any adjacent vegetation trimmed. The greater part of the smell attributed to sewage farms may be traced to accumulations of filth on the sides of carriers and on the overhanging herbage, etc. If properly attended to this should not occur.

Plough-formed sewage grips like those just mentioned should not be continued to the end of the field, but run out before the bottom of the plot is reached, otherwise in the event of a storm the sewage is washed over the plot.

Deposits taken from the carriers should be thrown at least six feet from the carrier's edges. These deposits generally contain sweepings from seed merchants' shops, etc., and if left near the carrier speedily form a dense growth over the carrier edges. When the carrier outlets are much above the level of the land they discharge on to, slabs may be placed for the sewage to fall on, or the sewage may be run on to the land by an ordinary earthenware pipe terminating in a T-piece spreading the sewage out to right and left, otherwise besides injuring the crops, holes are constantly washed in the soil, which, on a heavy soil, retain sewage after the field is dried, causing a smell.

Carriers require cleansing frequently or otherwise according to the amount they are used, the character of the sewage, and also according to the gradient at which they are laid and roughness of the carrier sides and invert. As a rule carriers require cleaning out from three or four times a year to once a month or oftener.

Speaking broadly, surface irrigation requires more carriers than filtration.

ROYAL COMMISSION ON SEWAGE DISPOSAL

SUPPLEMENTARY VOLUMES PRESENTED WITH THE

FOURTH REPORT

OF

THE COMMISSIONERS

APPOINTED IN 1898

TO INQUIRE AND REPORT WHAT METHODS OF

TREATING AND DISPOSING OF SEWAGE

(INCLUDING ANY LIQUID FROM ANY FACTORY OR MANUFACTURING PROCESS)

MAY PROPERLY BE ADOPTED.

VOLUME IV.

PART V.—REPORT TO THE COMMISSION BY DR. G. MCGOWAN, MR. R. B. FLORIS, A.I.C., AND MR. R. S. FINLOW, B.SC., ON METHODS OF CHEMICAL ANALYSIS AS APPLIED TO SEWAGE AND SEWAGE EFFLUENTS.

Presented to both Houses of Parliament by Command of His Majesty.

LONDON:
PRINTED FOR HIS MAJESTY'S STATIONERY OFFICE,
BY WYMAN AND SONS, LIMITED, FETTER LANE, E.C.

And to be purchased, either directly or through any Bookseller, from
EYRE AND SPOTTISWOODE, EAST HARDING STREET, FLEET STREET, E.C.; and
32, ABINGDON STREET, WESTMINSTER, S.W.; or
OLIVER AND BOYD, EDINBURGH; or
E. PONSONBY, 116, GRAFTON STREET, DUBLIN.

1904.

[Cd. 1886]—IV.

Presented by

Purchased

October 1908

REPORT

TO THE

ROYAL COMMISSION ON SEWAGE DISPOSAL

ON

METHODS OF CHEMICAL ANALYSIS AS APPLIED TO SEWAGE AND SEWAGE EFFLUENTS.

By Dr. G. McGowan, Mr. R. B. Floris, and Mr. R. S. Finlow.

6225 (v.). 1500.—Wt. 26170. 9/04. Wy. & S. a 2

EXTRACT FROM THE FOURTH REPORT OF THE ROYAL COMMISSION ON SEWAGE DISPOSAL. (1904. Cd. 1883).

28th December 1903.

"We have considered it desirable to publish, at this stage, the results and information which have been obtained by our own officers in regard to land treatment of sewage and methods of analysis, but we shall defer reporting on these matters until our investigations, which are now in progress, in regard to other methods of sewage treatment, are completed." (Paragraph 117, page xliii.)

TABLE OF CONTENTS.

	Page
Prefatory Note by Dr. McGowan	7
Method in which the Results of Analysis are expressed	9
Sampling of Sewages and Effluents, etc.	9
Preliminary Notes on Samples in the Laboratory	10
Determination of Free and Saline Ammonia	11
Determination of the Ammonia Correction in the distilled water used	12
Estimation of "Albuminoid" Ammonia	14
"Albuminoid" Ammonia from Distilled Water	15
Estimation of Free and Saline Ammonia by direct Nesslerization	15
Estimation of Nitrite by m-Phenylene Diamine	15
Estimation of Nitric and Nitrous Nitrogen together by the Copper-Zinc couple (Gladstone-Tribe Method)	17
On the Influence of Nitrite in an Estimation of Nitric plus Nitrous Nitrogen by this Method	19
Comparative Experiments on the Determination of Nitrate by the Copper-Zinc couple	21
Other methods of Estimating Nitrate	22
Approximate Estimation of Nitrate by Pyrogallic Acid	23
Kjeldahl Process for the Estimation of Total Nitrogen and (indirectly) of Total Organic Nitrogen	24
Kjeldahl "Blanks"	28
Estimation of Nitrates by the above Kjeldahl Method	31
Correction for Nitrite in the earlier Kjeldahl Estimations	33
Determination of Organic Nitrogen by the Kjeldahl Process without reduction	35
"Oxygen Absorbed" from Acid Permanganate	37
Incubator Test	41
Determination of Combined Chlorine	42
Gravimetric Estimation of Total, Suspended and Soluble Solids	44
Volumetric Estimation of Solids by the Centrifuge	47
Estimation of "Cellulose" in Sewages, etc.	48
The Action of an Acid Solution of Permanganate upon the Celluloses of Sewage	49
Estimation of the Dissolved Gases in Waters, Effluents, etc.	52
Determination of Dissolved Oxygen by the Copper Chloride method (Ramsay and Homfrey)	53
Determination of Dissolved Oxygen by Winkler's method as modified by Rideal and Stewart	55
Analysis of Soils	56
Analysis of Sludges	56
Heavy Metals in Sludges and in Effluents	56

Table of Contents—*continued.*

	Page
Appendix 1.—Changes undergone by Sewage when kept in a full bottle	57
Appendix 2.—Experiments showing the Breaking-down Effect of Water and Alkali upon Sewage	59
Appendix 3.—Volatilisation of Ammonia from very attenuated solutions of Ammonium Salts	60
Appendix 4.—The Comparative Stability of a dilute solution of Ammonium Nitrite	62
Appendix 5.—Loss of Nitrite when boiling down Effluents for estimation of Nitrate	64
Appendix 6.—No Loss of Nitric Nitrogen when Solutions containing Nitrate, etc., are evaporated	66
Appendix 7.—(1) Manganese Mud from Potash Residues in the Kjeldahl Estimation	68
(2) Some "Blank" Kjeldahl Estimations	68
Appendix 8.—Is there any quantitative relation between "Albuminoid" Ammonia, Alkaline Permanganate reduced, and "Oxygen absorbed" from Acid Permanganate?	70

PREFATORY NOTE BY DR. McGOWAN.

In presenting to the Commission the following Report upon Methods of Chemical Analysis as applied to sewage and sewage effluents, I wish to express my hearty thanks to the various assistants appointed under the Commission for the care and thoroughness with which the work has been carried out. Much the largest share of it has fallen to Mr. R. B. Floris, but Mr. Finlow also did a great deal; hence the following Report is a joint one by them and myself. Mr. Eric H. Richards, B. Sc., has during the past two and a-half years given most efficient help, not merely in carrying out the ordinary duties of the day, but also in improving various methods of analysis, while for the past year Mr. A. C. Carter, A.I.C., has also done excellent service. In the first year of the Commission Miss H. Chick, D.Sc., examined, along with myself, a number of the processes detailed in the following Report and materially helped forward the investigation; among other things, the work embodied in Appendices 2, 3, 4, and 7 (2) was done by her. I should also like to take this opportunity of thanking my colleague, Mr. Colin C. Frye, for a number of helpful suggestions made by him from time to time.

GEORGE McGOWAN.

Ealing, June 1904.

ROYAL COMMISSION ON SEWAGE DISPOSAL.

REPORT TO THE COMMISSION ON METHODS OF CHEMICAL ANALYSIS AS APPLIED TO SEWAGE AND SEWAGE EFFLUENTS.

By Dr. G. McGowan, Mr. R. B. Floris, and Mr. R. S. Finlow.

Method in which the Results of Analysis are Expressed.

All figures given in the following paper are expressed in parts per 100,000 *by weight*, excepting those referring to (a) solids (*i.e.* mud) as determined by the centrifuge, which are in parts per 100,000 *by volume*, and (b) those referring to dissolved gases, which are in parts per 1,000 *by volume* or c.c. per litre (at normal temperature and pressure). It is, however, convenient to give the figure for the absorption or taking up of dissolved oxygen in parts per 100,000 by weight also, to facilitate comparison with the "oxygen absorbed" from permanganate. This (in the main) was the system which was recommended a few years ago by a joint committee made up of a committee appointed by the British Association to report upon the subject, and a representative of the Commission. It would be a great convenience if this mode of expressing results were generally agreed to and adopted by chemists throughout the country and by managers of sewage farms or works, as such a course would greatly facilitate the reading and comparison of reports.

Sampling of Sewages and Effluents, etc.

The importance of good sampling cannot be over-rated, as upon this the whole of the deductions depend which are ultimately drawn from the figures of analysis. With regard to samples generally, every care should be taken to draw them in such a way as to maintain the true proportion of suspended solid to liquid. All samples, more especially effluents, should be drawn quietly, *i.e.*, without unnecessary aeration. Further, it is often advantageous to note the temperature of a sample when drawn. In most cases a half-Winchester quart bottle makes a sufficiently large sample, though for special purposes a Winchester is sometimes required. These are filled either full or with only a small air-bubble left at the top of the bottle, the stopper being then firmly inserted and tied down with a piece of calico. A rectangular wicker basket 16 to 17 inches long, by $6\frac{1}{2}$ inches broad at the top, by 13 inches high, with two partitions, holds comfortably three such half-Winchesters, $10\frac{1}{2}$ inches high, and allows at the same time plenty of room for paper packing; it is very rare for one of these bottles to be broken in railway transit.

When hourly samples of sewage, etc., are being taken, to be afterwards mixed in sets of 24 samples each, a wide-necked bottle of about 300 c.c.

capacity should be filled *completely* every hour and then set aside in a cool place ; at the end of 24 hours these sub-samples should be mixed for the final sample in proportions corresponding to the rates of flow at the respective hours as determined by a gauge. If circumstances do not permit of gauging, then the sub-samples can be mixed in equal volumes, and subsequent allowance made, as far as possible, when reviewing the figures of analysis, for the different factors which tend to cause the mixed sample to be either stronger or weaker than a true average sample taken according to rates of flow. Such hourly samples should of course be collected in normal weather. Excepting on very warm days there is no great change in a sewage (containing no oxidized nitrogen) or effluent within 24 hours after it is drawn. But if a sample cannot be examined on the day that it arrives at the laboratory, *it should if possible be kept in an ice box.*

In Appendix 1 are to be found four analyses of the same sample of sewage, which had been sub-sampled with the greatest care into four separate bottles, filled completely. These were kept in the light (so far as we can remember) at laboratory temperature for one, two, three and seven days. From the figures of analysis it will be seen that the sewage, in the absence of nitrate, underwent only slow change during the first two days.

An earlier experiment on the same lines with a sewage containing much nitrite and nitrate showed a rapid loss of nitrogen during the first day, but we should like to repeat the experiment before bringing forward any figures. This decomposition has, however, been well established by the work of Adeney and others.*

Preliminary Notes on Samples in the Laboratory.

Among the points to be noted, before the actual analysis is made, the following may be mentioned :—

1. *Colour.* This is of most consequence as regards effluents.

2. *Smell.* This, too, is of most importance in effluents. An effluent may have more or less of a sewage smell when drawn, and a clean smell when it comes to be analysed, the offensive putrescent matter having been oxidized in the interval by the dissolved oxygen and nitrate present. Still, a sample which smells of sewage when drawn is necessarily unsatisfactory. Generally speaking, an effluent which has no smell or an earthy smell is good ; when the smell becomes partly earthy and partly fishy or wormy, the effluent is not of such high class, though it may probably be still good. Sewages and tank liquors should be tested for sulphuretted hydrogen, *e.g.*, by holding a slightly moistened strip of acetate of lead paper inside the top of the bottle (*cf.* also distillation of free and saline ammonia, page 13).

3. *Reaction.* This we note by fragments of red and blue litmus paper (a) *in the cold,* allowing them to remain in a small quantity of the liquid for a short time. If they should then show acidity, (b) the liquid is boiled, in order to see whether the acidity is due to mineral acids or merely to carbonic acid. Domestic sewages and tank liquors and effluents from domestic sewages are almost invariably slightly alkaline, excepting percolation effluents from land, which are sometimes highly charged with carbonic acid. If a sample should be found to be permanently acid to any extent, the acidity should be determined before and after boiling (*cf.* also determination of free and saline ammonia, p. 14).

4. *Matter in Suspension.* The appearance and (apparent)† quantity of this should be noted, also its colour, whether it is flocculent, etc. Thus, in a sewage the fineness or coarseness is of great moment; when necessary, this sediment should be examined microscopically. Again, the amount of suspended matter in a tank liquor has a

(*) *Cf.* Gayon and Dupetit, (a) *Comptes Rendus*, Vol. 95, p. 644 (*Journ. Chem. Soc.*, Vol. 44, Abs. p. 679) ; (b) *Station Agronomique de Bordeaux*, 1886 (*Journ. Chem. Soc.*, Vol. 50, Abs. p. 823) ; Munro, *Journ. Chem. Soc.*, Vol. 49, p. 651.

(†) One is not infrequently at fault in making a mental computation of the *weight* of a given sediment (floating or settled), the state of aggregation varies so much.

manifest bearing upon the *life* of the filter bed on which the liquor is treated. Lastly, the quantity and appearance of the solids in an effluent should be carefully noted. If these solids are reddish-brown and well coagulated, the probabilities are that the liquid of the effluent is well or fairly well purified; but if they are grey and not well aggregated, the reverse is most likely the case.

5. It is also desirable to sometimes test an effluent qualitatively for *Lime, Sulphates, Ferrous* and *Ferric Iron*, etc., in case it should be in any way abnormal.

6. *Jointing.* By "jointing" is meant the attachment of a small piece of wide rubber tubing, A, about 7·5 c.m. (3 in.) long and 2 c.m. (0·8 in.) internal diameter, to the projecting rim of the neck of a bottle with a well-ground and tightly-inserted stopper, and then the pouring of some clean mercury into the rubber cup so formed (Figure 1). All access of air to the

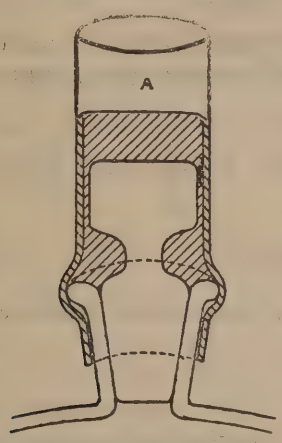


FIGURE 1.

liquid in the bottle is thus prevented. Should a piece of wide rubber tubing not be available, one (or two) small strips of narrower tubing may be slipped on to the rim, and a piece of glass from the end of a broken retort pushed tightly over that. The first arrangement ment is, however, the better, as in that case there is no chance of the joint being shaken loose. It is obvious that only bottles with a projecting rim wider than the stopper can be used here, *e.g.*, bottles of the Winchester quart type, and not those with wide, flat stoppers. A well-ground stopper, too, is essential; otherwise, with changes of temperature, the stopper may become loosened, and some mercury may find its way into the bottle.

A "jointed" sample means a sample which has been excluded from the air in this way, and then allowed to incubate at laboratory temperature; while the term "incubated" sample applies to one which has (generally) been jointed, and then placed in the incubator at a definite temperature for a given length of time before being examined.

DETERMINATION OF (A) FREE AND SALINE AMMONIA; (B) ALBUMINOID AMMONIA.

SOLUTIONS REQUIRED.

(1) *Ammonium Chloride.*—The ammonium chloride used should be either re-crystallised in small crystals or re-sublimed from the ordinary "pure" salt. It must leave no weighable residue when a reasonable quantity of it is vaporised at a *moderate* temperature in a platinum crucible, and it must also yield the theoretical amount of ammonia upon distillation with pure dilute potash into acid of known strength.

For a long time we used the solutions of the strength recommended by Wanklyn and Chapman in their well-known book on "Water Analysis," *i.e.*, containing respectively

(a) 3·15 grms. NH_4Cl per litre, and

(b) 0·0315 ,, ,, ,, (1 c.c. = 0·00001 grm. NH_3);

but, since in our analyses the figures for the nitrogen in its various forms in sewages and effluents are all expressed in terms of *Nitrogen*, it saves time when calculating results to make the solutions of the strengths :—

(a) 3·821 grms. NH_4Cl per litre ;

(b) 0·03821 ,, ,, ,, (1 c.c. = 0·00001 grm. N_2).

The stronger solution should either be kept in a bottle with a mercury joint, or else the bottle should be weighed when put aside and again weighed before any further liquid is taken from it for dilution (in order to ensure that there has been no sensible evaporation "through" the stopper). Not more than three-fourths of either solution should ever be used, the residue being discarded. Further, we have found it a useful precaution, as the result of experience, always to compare, by nesslerizing, a new dilute solution (b) with the residual portion of the solution (b) which has just been in use ; the two ought, of course, to agree.

(2) *Nessler Reagent.*—Prepared exactly as described in Wanklyn and Chapman's "Water Analysis," fifth edition, page 33.

(3) *Sodium Carbonate* (free from Ammonia).—An approximately half normal solution, *i.e.*, 26·5 grm. Na_2CO_3 per litre, is a convenient strength.

PROCESS.—(*a*) *Estimation of Free and Saline Ammonia.*

For the actual estimation of Free and Saline and of Albuminoid Ammonia we have used both glass-stoppered retorts and large round-bottomed glass-stoppered flasks (of the shape of an ordinary fractionating bulb), each having a capacity of about 2 litres. The time required for the distillation is in both cases almost the same, and we find no appreciable difference between the results obtained. For condensation, Liebig's condensers have been employed. A few recent comparative estimations, made with a Cribb's condenser (with the object of saving space upon a small bench), have likewise given similar results. It would thus appear that if the time required for distillation is fairly constant, and if the temperature of the distillate when nesslerized does not vary appreciably, the choice of a distillation apparatus is a matter for personal convenience.

The distilling flask or retort having been carefully cleaned, it is attached to the condenser by a narrow ring of indiarubber (a few m.m. wide when stretched), the neck of the flask or retort which delivers into the condenser tube projecting at least 2·5 c.m. or one inch below the rubber band. About 200 c.c. of distilled water are now run in, and at least 50 c.c. of this are distilled over. Should this final cleansing by distillation be omitted, small, but appreciable, traces of ammonia from the vessels themselves may be (wrongly) included in the first distillate of an actual estimation.

Determination of the Ammonia Correction in the Distilled Water used.

The above residual water is now emptied out of the distilling vessel, 500 c.c. of good distilled water (a) are poured in, and 100 c.c. of the latter are distilled off into a stoppered measuring flask of that capacity. This distillate (which will contain all the free ammonia from the 500 c.c. of water) having been thoroughly mixed by shaking, 50 c.c. of it are poured into a Nessler glass, and 2 c.c. of Nessler reagent are added ; while into a similar glass 50 c.c. of distilled water from the same stock bottle (a) are placed, and sufficient dilute ammonium chloride solution is run in from a burette to enable the mixture to give with 2 c.c. of Nessler reagent a tint of exactly the same depth as that obtained from the above 50 c.c. of water distillate. If the correct

quantity of ammonium chloride has not been added, the depths of tint will not be identical, and a fresh standard must be made containing the requisite amount of ammonium salt. As is well known, it is never permissible, in nesslerizing, to increase the quantity of ammonium chloride in the standard *after* the Nessler reagent has been run in. The volume of ammonium chloride required is then read from the burette and multiplied by 2, so as to give the amount corresponding to the total distillate of 100 c.c. But, since 50 c.c. of the distilled water (a) have been used in making up the standard for comparison with half of the distillate, the ammonia in the entire distillate from 500 c.c. of (a) must be equal to the ammonia in the ammonium chloride used *plus* that contained in 100 c.c. of (a); or, the ammonium chloride added corresponds to the ammonia in (500—100 =) 400 c.c. of the original distilled water. *One-eighth* of this amount of ammonium chloride—*i.e.*, the amount corresponding to the ammonia in 50 c.c. of the distilled water (a) must therefore be added to the burette reading for each 50 c.c. of distillate nesslerized in an actual estimation, since the ammonium chloride required for the standard in any particular case is necessarily less than the true amount by the equivalent of ammonia already found in the 50 c.c. of distilled water used in making up that standard.

The above correction must, of course, be determined for every fresh bottle of distilled water used. It should not exceed 0·2 c.c. of dilute ammonium chloride, and we usually find it to be about half that amount. Distilled water from naturally pure waters would, of course, not give so much. With care, a Winchester quart of water can be made to serve for two analyses.

After the 400 c.c. of ammonia-free water in the distilling vessel have cooled somewhat, the sewage or effluent is added by means of a pipette* and a long-stemmed funnel, the neck or tubulus of the warm flask or retort being protected from the cold funnel by encircling the shoulder of the latter with about an inch of rubber tubing, split two or three times parallel to its axis for half its length; the liquid adhering to the funnel is finally rinsed into the distilling vessel with 50 c.c. of distilled water.

The quantity of the sample taken for analysis should be such as to give a distillate for the free and saline ammonia that will correspond to *not more* than 15 to 20 c.c. of the dilute ammonium chloride solution. One usually takes the equivalent of 1 or 2 c.c. of a sewage, and from 5 to 20 c.c. or even up to 50 c.c. of an effluent, according to its quality.† Before a sewage or an effluent can be sampled in this way, the liquid and solid in it must be thoroughly mixed by stirring up with a thick piece of bent glass rod tipped with rubber. Even then the sampling of a sewage is not always satisfactory. And since it is next to impossible to pipette out 1 or 2 c.c. so as to represent a fair sample of the sewage, a dilution is first made with, say, 25 c.c. sewage plus 225 c.c. of the same distilled water as is used for the blank (*i.e.*, a dilution of 1 in 10), and then 10 or 20 c.c. of this diluted liquid are taken for the actual distillation. This obviates the error of reading very small volumes of liquid, while it also probably gives a truer sample of the mixed liquid and solid. The ammonia in the diluting water is subsequently allowed for.

Should sulphides be present in the sample to be analysed,‡ sufficient, but no appreciable excess of, sodium carbonate solution (usually 5 or 6 drops) must be added to prevent sulphuretted hydrogen passing over into the distillate; but this addition is not to be recommended in any other case, because of the hydrolysing action of alkali upon the organic matter of a sewage or effluent. (See Appendix 2 for the distillation of sewage with water and with different alkaline solutions.) The glass of the distilling vessel

---

* It is advisable to have a small well-packed plug of cotton wool near the mouth-end of the pipette.

† The amount to be taken is arrived at roughly by a preliminary direct nesslerization of a small quantity of the sewage or effluent, sufficiently diluted.

‡ We have sometimes fallen into error by omitting to test for sulphides before distillation.

furnishes sufficient alkali to ensure all the free and saline ammonia being driven off in the case of ordinary sewages and effluents. (*Cf.* Appendix 3.) But any non-volatile free acid which may be met with in sewages containing certain trade effluents must, of course, be neutralised in the first instance.

Distillation is then proceeded with, the first fraction being usually one of 150 c.c., which is cooled if necessary§ and an aliquot portion of it nesslerized. The actual time of distillation of these 150 c.c., from the commencement of the boiling, is about 15 to 16 minutes. The distilled water correction is applied for 100 c.c. only of this fraction, since 50 c.c. of distilled water were used for rinsing the funnel into the distilling vessel. The next fraction is one of 50 c.c., and the whole of this is nesslerized; it is usually either free from ammonia or contains only a trace of the latter. Should, however, more ammonia be found in it than corresponds to, say, 0·4 c.c. of the dilute ammonium chloride solution, a further quantity of 50 c.c. of distilled water must be added to the residue in the retort, and an equal volume distilled off and nesslerized. But, though this is advisable as a precautionary measure, the last-mentioned distillate is almost invariably found to be ammonia-free. The sum of the amounts of ammonium chloride used in nesslerizing, plus the small distilled water correction, represents the free and saline ammonia in the quantity of sample taken; but this we express in terms of nitrogen as *Ammoniacal Nitrogen.*

B.—*Estimation of "Albuminoid" Ammonia.*

Solution required (in addition to those already given for the determination of Free and Saline Ammonia):—

4. *Alkaline Permanganate of Potash.*—This is made, after Wanklyn and Chapman, by dissolving 200 grms. of stick caustic potash and 8 grms. of potassium permanganate in about 1½ litres of distilled water, which is conveniently done in a basin of tinned iron. The solution is then gently boiled until it is reduced to a volume of about 800 c.c.; after cooling, it is siphoned into a litre flask and made up to 1 litre with ammonia-free distilled water.

It is tested by adding 25 c.c. of it to about 250 c.c. of ammonia-free distilled water in a retort, distilling over 50 c.c., and nesslerizing this distillate; the latter must show no ammonia.

Process.—When the residue from the estimation of free and saline ammonia has cooled considerably, 25 c.c. of the alkaline permanganate are added to the retort or distilling flask from a pipette, and the distillation is proceeded with. The fractions collected are usually three—of 100, 50, and 50 c.c. respectively. After mixing the first fraction thoroughly, a suitable quantity of it is nesslerized and the "albuminoid" ammonia in the whole fraction is calculated; the other two fractions of 50 c.c. are each nesslerized as a whole. The distilled water correction is of course again applied for each nesslerization. The sum of the "albuminoid" ammonias in these fractions is expressed in terms of "*Albuminoid Nitrogen.*"

In actual practice this distillation is never carried further than the 200 c.c. indicated above, no matter at what rate the albuminoid ammonia may be coming off when this limit is reached. The estimation is thus only approximate, at least in the case of a sewage or an ordinary effluent. If the distillation of these was carried further (with the addition of successive quantities of ammonia-free water to the retort), albuminoid ammonia would be obtained for an indefinite period in gradually decreasing amounts in the successive fractions of the distillate.

The remarks made on p. 12 with regard to the figures obtained for free and saline ammonia by distillation in glass vessels of different shape apply here also. At the same time, in view of some discrepancies which we have ourselves experienced, it might perhaps be well if some general agreement could be arrived at by chemists, both with regard to the limits of concentration of a solution of sewage or effluent to be distilled, and also

§ The influence of temperature upon the depth of tint produced in nesslerizing is well known.

to the length of time that may be allowed for such distillation in the estimation of both free and albuminoid ammonia.

NOTE.—"*Albuminoid*" *Ammonia from Distilled Water.*—We have more than once been seriously inconvenienced by obtaining an appreciable albuminoid ammonia blank from our distilled water (distilled in a continuously-fed copper still from the water of the Grand Junction Water Company). This blank has reached the equivalent of 0·5 c.c. dilute ammonium chloride, and at one time as much as 1·0 c.c., from the permanganate distillation of 500 c.c. copper-distilled water, after the free ammonia had been driven off. This finding of "albuminoid" ammonia is more especially the case in times of storm, when the water is decidedly coloured. It is difficult to see where this "albuminoid" ammonia can come from, but the fact remains that we have frequently found it. Possibly some volatile nitrogenous compound (not ammonia) is evolved in the copper still from the action at 100° C. of accumulated carbonate of lime and of water upon dissolved or precipitated organic matter. Various suggestions have been made (*e.g.*, the interposition between the still and the receiving bottle of a flask containing water acidulated with sulphuric acid, to be kept boiling), with the view of eliminating both free and albuminoid ammonia from the distilled water. The point will be investigated when time allows, but the practical difficulties are considerable. The above results, however, show the necessity for occasionally testing distilled water for an albuminoid ammonia blank, and rejecting any bottles in which this is at all appreciable.

Estimation of Free and Saline Ammonia by Direct Nesslerization.

We have made a great many attempts to determine the free and saline ammonia in sewages and effluents by direct nesslerization, *i.e.*, without a preliminary distillation, the sample being, if necessary, rendered clear by filtration through German filter paper. But out of 188 samples so examined — most of them effluents from land — 129 were too turbid to allow of their being read properly. The turbidity appeared simultaneously with the addition of Nessler reagent to so much of the sample, diluted to 50 c.c. with distilled water, as would correspond to not more than about 2 c.c. of the dilute ammonium chloride solution. Of the remaining 59 samples which we were able to read by this method, 35 gave results within 10 per cent. of the corresponding distillation figures, while 27 samples—*i.e.*, about 15 per cent. of the total number examined—were within 5 per cent.

It has been suggested that the sample should be allowed to stand in a full bottle with a known volume of pure potassium oxalate solution (ammonia free), in order that the lime might be brought down before nesslerizing. But as the ammonia present changes with lapse of time, unless the solution is sterilized, the results thus obtained might not be strictly comparable with the rest of the analysis; and, further, we have found that such precipitation of the lime does not always prevent turbidity occurring upon the addition of the Nessler reagent. The adsorptive effect of a precipitate of oxalate of lime upon ammonia present in solution is probably also appreciable (*cf.* p. 36).

While our experience is therefore against the quantitative estimation of free and saline ammonia by direct nesslerization, the latter may be found useful for giving an approximate result when there is no time for distillation.

ESTIMATION OF NITRITE BY META-PHENYLENE DIAMINE.

We have used this well-known colorimetric method throughout the whole of our work.

Solutions required—

(1) *Potassium Nitrite*, containing about 0·00004 grm. of Nitrous Nitrogen per c.c. The preparation of pure potassium nitrite is troublesome, and the ordinary salt containing some nitrate does equally well.* The solution must, however, be standardised, both in the first instance and from time to time afterwards, by means of a solution of potassium permanganate of known strength, the excess of permanganate—above that required to oxidize the nitrite to nitrate—being afterwards determined by standard thiosulphate and potassium iodide in the ordinary way (*cf.* Sutton's *Volumetric Analysis*, 7th edition, p. 267).

When making a nitrite determination in a sample of effluent, 10 c.c. of the above solution are diluted to 100 c.c. with distilled water; 1 c.c. of this latter solution therefore contains about 0·000004 grm. Nitrous Nitrogen.

* *Note*—In Appendix 4 are given the results of several experiments showing the stability of dilute solutions of Ammonium Nitrite in distilled water.

(3) *Sulphuric Acid.* 1 part by volume of strong sulphuric acid (free from nitrite) to 2 volumes of distilled water.

(4) *Meta-Phenylene Diamine.* 1 grm. of this substance is dissolved in 200 c.c. of distilled water acidified with 2 c.c. of concentrated sulphuric acid. If the solution should be brown, it must be decolorised by letting it stand over animal charcoal and then filtering. A charcoal containing no phosphate would probably be better. Such a charcoal can be made by saturating Kieselguhr with a suitable organic liquid, drying, and subjecting the mass to dry distillation. The decolorising power of this charcoal is comparable with that of ordinary bone char.

Method.—A preliminary trial is made in a Nessler glass with 25 c.c. of the sewage or effluent (filtered unless the sample happens to be clear), by adding to it 1 c.c. each of the sulphuric acid and the *m*-phenylene-diamine solutions, mixing thoroughly, and allowing to stand for 20 minutes. A comparative experiment is at the same time made with, say, 4 c.c. of the *dilute* potassium nitrite solution, also diluted to 25 c.c. with distilled water. At the end of this time the tints are compared, and such a quantity of the sample is taken for the actual estimation as is calculated to give a tint equal in depth to that produced by, say, 4 c.c. of the dilute standard solution, this being a convenient depth of (yellow) colour to read.

The estimation can be done most quickly if several standards are prepared together. Thus, if after the preliminary trial 20 c.c. of the sample were thought to be the proper amount, four standards might be made containing respectively 3·65, 3·80, 4·05, and 4·30 c.c. of the dilute nitrite solution in 50 c.c. distilled water; one of these would probably match the tint given by the sample. As the yellow colour becomes darker on standing, it is of course essential that sample and standards should have the *m*-phenylene-diamine added at the same time.

For a reading which is close to, but not exactly the same as, one of the standards, the exact value can be obtained fractionally. Thus, if both sample and standard have been diluted to 50 c.c., and it is found that 48·5 c.c. of the 4·05 standard give a depth of tint equal to that of the sample, then $(4{\cdot}05 \times \frac{48{\cdot}5}{50} =)$ 3·93 c.c. of the nitrite solution will represent the amount of nitrous nitrogen in the volume of sample taken. This fractional method can, however, only be applied within limits of about 0·5 c.c. of the nitrite solution; over wider limits the depth of colour produced is not strictly proportional to the nitrous nitrogen present.

Results are expressed in terms of *Nitrous Nitrogen* per 100,000.

Estimation of Nitric and Nitrous Nitrogen together, by reduction to Ammonia with the Copper-zinc couple (Gladstone-Tribe Method).*

Reagents Required.—(1) and (2) Standard solution of *Ammonium Chloride* and *Nessler Reagent* (see pp. 11–12):—

(3) A 3 per cent. solution of crystallized Sulphate of Copper ($CuSO_4 + 5Aq$).

(4) Pure dry *Sodium Chloride*, prepared as given on page 42.

(5) Solution of *Bicarbonate of Lime*, prepared by saturating lime water with washed carbonic acid gas. Such a solution contains about 0·00304 grm. CaO in 1 c.c.

(6) Pure thin *Zinc foil* (see below). It is an unnecessary expense to have this foil thick. A piece which measures about 10 c.m. (4 in.) by 7 c.m. (2¾ in.) need not weigh more than 2 to 3 grammes.

Method.—We have used this well-known method throughout our work and have found it most satisfactory. One great point is *not to take more* of the sample for nitrate estimation than will ultimately correspond to about 15 c.c. or so of the standard dilute ammonium chloride. Since the land samples were examined, we have added—as preliminary and supplementary to this process—the approximate method with pyrogallic acid, which is described on page 23. A preliminary trial with pyrogallic acid (which can be carried out in a few minutes) tells one pretty nearly how much nitrate and nitrite have to be dealt with, and thus greatly helps the correct quantitative estimation, this being especially the case with highly nitrated effluents. Before we adopted this plan, the volume of sample taken for nitrate estimation by the couple had to be more or less guessed at, the consequence being that sometimes too much was used, and a nitrate value in some cases obtained which was appreciably below the true value.

Another important preliminary is to know the amount of free and saline ammonia in the sample. This has either been determined in the first instance by distillation, or, at all events, an approximate idea has been obtained by a direct nesslerization. This latter is in truth the best plan, for it enables the nitrate estimation to be carried out without any loss of time, *i.e.*, without the sample having had a chance of undergoing change.

(a) If the amount of ammoniacal nitrogen is comparatively small, say, not more than one part per 100,000, or if it is not greater than the nitric nitrogen as determined approximately by pyrogallic acid, then 10 c.c. or less of the sample, filtered† if it contains any appreciable solid, is measured by means of a pipette into a wide-mouthed bottle of about 100 c.c. capacity, fitted with a well-ground stopper, 0·2 grm. of the sodium chloride is added,‡ and the bottle is then filled up to the shoulder with distilled water.

---

* Note.—Some early attempts were made to destroy any nitrite present before estimating nitrate, by boiling down the liquid with 0·5 c.c. sulphuric acid. But even when the volume of the liquid had been reduced in this way from 100 c.c. to 25 c.c., much nitrite remained. It was therefore necessary to determine both together, and to subsequently deduct the nitrite as determined by meta-phenylene-diamine (p. 16).

† The filtration of samples, whether it be for the determination of nitrite, nitrate, or chlorine, etc., is a point deserving attention. The whole of the filter paper in the funnel should be washed several times with the liquid in question, and these washings be rejected; otherwise the paper may either give up traces of ammonia to the liquid or absorb some constituents from the liquid, or it may do both.

‡ The addition of the sodium chloride, to accelerate the action of the couple, is absolutely necessary; if it be omitted, the figure obtained for nitrate in a well-nitrated effluent will almost certainly be too low.

The copper-zinc couple is prepared by loosely rolling a strip of well-cleaned zinc foil,* in the direction of its length (about 10 c.m., or 4 inches), and then leaving it completely immersed in some of the 3 per cent. copper sulphate solution (which is never used more than once) until a firmly adherent coating of copper has been deposited on it; this usually takes about 20 minutes. The roll is then taken out with a pair of forceps, washed well under the tap, and finally in a stream of distilled water, and placed in the already (nearly) filled estimation bottle, the stopper of which must be firmly inserted. Experience has taught us that *a fresh couple must be prepared for each estimation.* If the zinc of a couple, after being cleaned, is used a second time, the copper then appears to be more loosely deposited on it, with the result that the ammonia dribbles over more slowly when the liquid is distilled.

A similar bottle, filled in precisely the same way, excepting that no couple is added to it, gives the "blank," *i.e.*, the free and saline ammonia in the sample and reagents, and no doubt also a little ammonia resulting from the hydrolysis of the organic matter present.

The two bottles are placed in the incubator at 26·7° C. (80° F.) overnight, and next morning the respective contents, plus 100 c.c. of distilled water used for rinsing out each bottle, are distilled from two similar stoppered retorts of about 500 c.c. capacity each. Both distillates are collected in two separate fractions, the first fraction of 100 c.c. being received in a stoppered flask of that size, and the second fraction of 50 c.c. in a Nessler glass.

After shaking up the first fractions from both distillates, two equal measured amounts from both flasks—say 10 c.c. diluted to 50 c.c. with distilled water—are nesslerized separately. By comparing the depths of tint thus produced, an idea is gained of the amount of ammonium chloride which it would be necessary to add to the "blank" distillate in order to make it give as deep a colour with the Nessler reagent as the "couple" distillate does. This operation is repeated at one and the same time with suitable equal quantities of the two distillates until the exact amount of ammonium chloride is determined, which—calculated for the whole 100 c.c. of distillate—corresponds to the nitric plus nitrous nitrogen originally present in the volume of sample taken.

The second fraction of 50 c.c. from both distillates is usually ammonia-free, but it is advisable to add Nessler reagent to the "couple" 50 c.c. first. Any slight colour can then be compensated for, before nesslerizing the "blank" 50 c.c. (which is itself almost invariably ammonia-free), by adding the requisite amount of ammonium chloride to the latter. The ammonium chloride used for this second fraction must of course be added to that required for the first in calculating the total nitric + nitrous nitrogen present. It only remains to deduct the nitrous nitrogen (determined as on p. 16) from this, to get at the nitric nitrogen in the sample.

(*b*) If, on the other hand, much free and saline ammonia are present, 10 c.c. to 50 c.c. (usually 25 c.c.) of the sewage or effluent, filtered if necessary, are diluted to about 150 c.c. with distilled water, 5 c.c. of the calcium bicarbonate solution are added, and the whole is boiled down to about 20 c.c. in a round-bottomed Jena flask, *in a draught cupboard.* This drives off practically all the free and saline ammonia, the presence of the lime salt ensuring the stability of any nitrite present (*cf.* pp. 20–21). The cooled solution is made up to a given volume—say 100 c.c.—with distilled water, and suitable quantities (usually the equivalent of 10 c.c. of the original) are taken both for the "blank" and for the estimation proper.

This boiling down, when much ammonia relatively is present, is of course necessitated by the circumstance that this ammonia appears both in

* The actual size of the strip which suits the bottle we use is about 10 c.m. (4 in.) by 7 c.m. (2¾ in.) and this strip is rolled into a coil.

the "blank" distillate and in the distillate from the estimation itself. Since the amount of ammonia to be nesslerized cannot be increased beyond a given limit, save at the expense of accuracy, a much smaller quantity of the sample would have to be taken if there was no boiling down—a quantity in many cases too small to give the accurate figure for the nitrate present.

Experiments made with pure solutions of potassium nitrate have shown that, in order to secure the best results, the liquid to be actually reduced by the couple should not contain more than about 0·2 part nitric + nitrous nitrogen per 100,000, *i.e.*, the ammonia to be actually obtained should not exceed 0·0002 grm. (nitrogen). Quantities of oxidized nitrogen which are markedly in excess of this amount are not always entirely reduced in 18 to 24 hours at a temperature of 26·7° C. (80° F.). But when the above-mentioned conditions are observed, we have found the process to be accurate to within 2 or 3 per cent. either way, this being about the limit of accuracy in nesslerizing a pure solution of ammonia.

On the Influence of Nitrite in an Estimation of Nitric plus Nitrous Nitrogen by the Copper-Zinc Couple.

Sewages and sewage effluents from land usually contain little or no nitrite, as a reference to the various Tables of Analysis shows;* further, the effluents are generally well supplied with carbonate of lime in solution. Hence it did not occur to us until all, or nearly all, the land samples had been examined that there might possibly be loss of nitrous nitrogen in certain classes of effluents when boiling down for the nitrate estimation. But on examining (for another purpose) an effluent from a bacterial filter which was unusually rich in nitrite, containing as much as 1·43 parts nitrous nitrogen per 100,000, it was apparent that the boiling down led to a loss of nitrogen equal to nearly half of the total nitrous nitrogen present. Experiments were, therefore, made in order to see whether the boiling down process gave rise to the loss of either nitrous or nitric nitrogen, or both, in sewages and land effluents.

It will be best to consider the Nitric Nitrogen first.

1.—*Nitric Nitrogen.*—Our experiments showed that no measurable loss of nitric nitrogen took place when solutions containing varying quantities of potassium nitrate, ammonium chloride and carbonate, and sodium chloride (quantities approximating to those met with in ordinary effluents) are boiled down from 150 c.c. to about 20 c.c. Six estimations made in this way gave a mean loss of 1·7 per cent. of nitric nitrogen—a quantity well within the limits of nesslerizing error. The details of these experiments are given in Appendix 6.

A further series of estimations was made with solutions containing no sodium chloride, but similar amounts to the above of ammonium chloride and carbonate, potassium nitrate, and potassium nitrite. In these experiments the loss of nitrous nitrogen, due to boiling down, was shown by the difference given by *m*-phenylene diamine before and after, while the nitric and nitrous nitrogen together were similarly determined by the "couple" method. This gave:—

(*a*) Nitric + Nitrous Nitrogen in original liquid;

(*b*) Nitric + Nitrous Nitrogen in boiled-down liquid;

(*c*) Nitrous Nitrogen in original liquid;

(*d*) Nitrous Nitrogen in boiled-down liquid.

$\therefore$ $a—c$ = Nitric Nitrogen in unboiled liquid;

$b—d$ = Nitric Nitrogen in boiled-down liquid.

* Part II., Chemical Report by Dr. G. McGowan.

Any loss of nitric nitrogen due to boiling down would therefore be indicated by obtaining a smaller value for *b—d* than for *a—c*.

The mean result of a series of seven such experiments showed a loss of only 0·07 part Nitric Nitrogen per 100,000, *i.e.*, *nil*; the average loss of Nitrous Nitrogen was 0·25 part. (For details, see Appendix 5.)

2. *Nitrous Nitrogen.*—It was found that with pure dilute solutions of potassium nitrite, containing 0·1 to 0·2 part nitrous nitrogen per 100,000 and only a trace of nitrate, no loss of nitrite occurred in boiling down. But on boiling down a salt solution containing 6·04 parts ammoniacal nitrogen, 7·84 parts chlorine, and 1·09 parts nitrous nitrogen (added as potassium nitrite), a mean loss in two experiments of 32 per cent.* of the nitrous nitrogen took place during the usual concentration from 150 c.c. to about 20 c.c. It was further found that the percentage loss of nitrous nitrogen remained practically constant even when the nitric nitrogen was increased to 5·4 parts per 100,000, for the same quantity of nitrite, *i.e.*, the nitrate present had no effect one way or the other. (*See* Appendix 5.)

It is thus evident that any loss of oxidized nitrogen on boiling down is entirely borne by the nitrite present, and that the latter is not oxidized to nitrate in the process, at all events, not in any appreciable quantity. We should imagine that the decomposition is one of ammonium nitrite into nitrogen and water, but we are not aware of any quantitative experiments to prove this in the case of such dilute solutions as are dealt with above.

That this loss of nitrous nitrogen, and, incidentally, of ammoniacal nitrogen, is only effected after a certain degree of concentration is attained —a degree outside the range of the ammonia determination process (p. 13) —is proved by the following experiments which were done in order to make sure that no ammonium nitrite was decomposed in the extremely dilute solutions which are employed in the determination of free and saline ammonia. In these experiments the ammonia was of course estimated in the distillate and the nitrite in the residue.

Ammoniacal Nitrogen (Grms.)				Nitrous Nitrogen (Grms.) taken as Potassium Nitrite.			Volume of Li (c.c.).	
In form of :—	Taken.	Found.	Difference per cent.	Taken.	Found.	Difference per cent.	Initial.	Fin
Ammonium Carbonate	0·0001252	0·0001300	— 4·6	0·0001244	0·0001244	± 0·0	500	2
Ammonium Chloride	0·0001252	0·0001229	+ 1·9	0·0000394	0·0000390	— 1·0	475	2
Ammonium Chloride	0·0001244	0·0001190	+ 3·7	0·0000392	0·0000392	± 0·0	475	2
Ammonium Carbonate and Ammonium Chloride in equal proportions	0·0001350	0·0001391	— 3·0	0·0000400	0·0000390	— 2·5	494	2
		Mean	0·5 p.c. Gain.			0.9 p.c. Loss.		

The foregoing experiments, taken as a whole, made it appear probable that loss of nitrous nitrogen in boiling down would be prevented if there was present a *stable* base considerably in excess of the amount necessary to combine with all the nitrous acid. It was only after these experiments had been completed that we found that this point—the destruction of nitrite—had already been observed by P. Frankland† in solutions of a some-

* The separate figures were 29·2 per cent. and 33·8 per cent.

† *Journ. Chem. Soc.*, Vol. LIII., p. 368 *et seq.*

what different kind, but we have thought it well to give here our own independent and corroborative experience on the subject.

The base first tried was the potash which we used in our *Kjeldahl* process (p. 24); this having been purified by permanganate probably contained traces of nitrate. On boiling down with potash (0·085 grm. KOH) solutions of the same composition as had given a loss of 32 per cent. of the nitrous nitrogen when there was no addition of base (p. 20), the mean loss in four experiments was – 5·9 per cent., *i.e.* a gain of this amount. Calcium bicarbonate solution (5 c.c.) was therefore next tried in place of potash, with the result that the mean of four determinations (two being boiled down lower than they should have been) showed a loss of nitrous nitrogen equal to nearly 4 per cent., a figure which is probably within the limits of accuracy of nitrite determination by *m*-phenylene-diamine.

The detailed figures of this last set of experiments are :—

Grms. Ammoniacal Nitrogen taken.	Grms. Chlorine taken.	Grms. Nitrous Nitrogen taken.	Grms. Nitrous Nitrogen found.	Loss of Nitrous Nitrogen.	% Loss of Nitrous Nitrogen.
0·0015	0·00196	0·000272	0·000272	0·0	0·0
* 0·0015	0·00196	0·000272	0·000261	0·000011	4·0
* 0·0015	0·00196	0·000136	0·000127	0·000009	6·8
0·0015	0·00196	0·000136	0·000129	0·000007	5·1

* Boiled rather lower than the others.

The above results are very much like those obtained from similar experiments made with the Rugby, Leicester, and Beddington sewage farm effluents, all of which contained plenty of lime salts. On the other hand, the effluents from Caterham Barracks and Aldershot Camp Farm, in which loss of nitrite when boiling down for nitrate was first observed, had much less lime in solution. A reference to the Chemical Section of the Report on Land Treatment of Sewage, p. 300,* will show that the amounts of lime found in the soils and subsoils of the farms just mentioned are in accordance with this.

We therefore now make it a rule, when boiling down a sewage or an effluent for nitrate determination, to add beforehand 5 c.c. of calcium bicarbonate solution (page 17) if nitrite is present.

Comparative experiments on the determination of Nitrate by the copper-zinc couple :—(A) *Distilling and Nesslerizing the ammonia, as above ; and* (B) *Precipitating the lime in the reduced solution by oxalate,*† *filtering, and Nesslerizing directly.*

A few such comparative estimations were made, a small measured quantity of pure potassium oxalate solution being added in the case of (B)

* Part II., Chemical Report, by Dr. G. McGowan.

† M. Whitely Williams, *Journ. Chem. Soc.* for 1881, p. 100; also Sutton's *Volumetric Analysis*, 7th edition, p. 434.

to both the "blank" and the estimation proper: these two liquids were then filtered next day and nesslerized directly. The following results were obtained :—

Sample.	Nature of Sample.	Parts Nitric Nitrogen per 100,000.	
		(A) Distillation.	(B) Oxalate.
No. 155B	River water containing effluent.	0·53	0·56
156A	River water.	0·51	0·48
157	Final effluent over three fields.	0·81	0·77
160A	River water containing effluent.	0·50	0·54
166A	River water containing effluent.	0·53	0·51
	Mean - - - -	0·59	0 57

Any absorption of ammonia by the oxalate of lime (*cf.* p. 36) would affect both "blank" and estimation, but whether to the same extent we have no evidence.

The above comparative figures leave little to be desired, for the differences are practically within the limits of experimental error. But in some further estimations of the same kind, the liquids (after filtration from the oxalate of lime) became turbid on addition of the Nessler reagent, and hence no result could be arrived at. For this reason we have not carried the matter further; and there is, besides, little time saved by adopting the oxalate modification of the process.

Other Methods of Estimating Nitrate.

(*a*) The *Picric Acid Method*, depending upon the formation of yellow ammonium picrate, is well known and is frequently made use of, but we have only had a limited experience of it. It apparently works well with samples of drinking water, but we found that, with effluents containing any notable amount of organic matter in solution, a green or brown coloration was ultimately obtained which could not be compared with the standard yellow tints. The method has the further disadvantage of requiring the use of strongly ammoniacal solutions. We have therefore never made use of the method as a standard one, but at the same time we do not feel justified in expressing any very definite opinion upon it.

(*b*) The *Indigo Decolorisation Method.*—We also made some trials of the two modifications of this well-known method, viz. :—

(1) By measuring directly the volume of a standard solution of pure indigo-carmine (made by dissolving the dry substance in Nordhausen sulphuric acid and then diluting) which is de-

colorised by the nitrate in a solution containing a large excess of sulphuric acid.

(2) By measuring this indirectly, *i.e.*, adding excess of the indigo solution in the first instance, and ultimately titrating that excess with standard permanganate.

The results obtained by us, however, were not sufficiently encouraging to warrant the adoption of either modification. But here, again, our experience has been limited.

Nitrate: Approximate Estimation of, by the Pyrogallic Acid Method.

This colorimetric method (due to a reaction which, so far as we can ascertain, is not understood) was worked out by J. Horsley so long ago as the year 1863 (*Chem. News* for June, 1863, p. 268), but is apparently unknown to most people; we are much indebted to Mr. R. Wallis Stoddart, who has used it for a long time, for telling us of it. The method lays no claim to be perfectly exact, *i.e.*, quantitative, but after a little practice one can arrive in a few minutes at a very fair idea of the amount of nitrate in any given sample, or, at all events, in nearly every sample (*cf.* p. 24). The following are the details of the process as we carry it out:—

10 c.c. of the sample, *filtered from all suspended solids*, are poured into a test tube of rather thick glass (a bacteriological test tube 15 c.m. or 6 in. long by 1·25 c.m. or 0·5 in. in diameter), and about 0·2 grm. of pyrogallic acid is dissolved in this and the solution made uniform. After the first two or three trials it is unnecessary to weigh this acid, as it can then be measured out with sufficient accuracy. By means of a small pipette, *plugged at the upper end with a piece of cotton wool*,* and lowered to the bottom of the test tube, 2 c.c. of concentrated nitrate-free sulphuric acid are allowed to flow slowly down on to the bottom of the tube, so as to form a layer below the aqueous one. Before withdrawing the pipette, its upper end must be closed by the finger, in order to prevent the acid still remaining in it from mixing with the aqueous layer of liquid. About 0·1 grm. of *pure dry powdered* sodium chloride (which, like the pyrogallic acid, need only be weighed once or twice) is then dropped into the tube, and falling—as much of it does—on the junction of the sulphuric acid and the water, it gives rise to a brisk effervescence. Should nitrate be preseut, a purple band forms at this junction, the intensity of the colour produced being proportional to the amount of nitrate.

A preliminary trial gives a rough idea of this amount, after which a second estimation is made along with three other simultaneous determinations with similar volumes of standard potassium nitrate solution. Thus, if the preliminary trial shows, *e.g.*, about 0·6 part of nitric nitrogen per 100,000 parts of liquid, the three standards are made to correspond to 0·4, 0·6 and 0·8 parts. In this way the nitric nitrogen in the sample may be gauged to within about 0·25 part per 100,000. It is, however, essential that the determinations should be carried out at the same time in both sample and standards, i.e., one following immediately on the other, for it is useless to try to compare two tubes unless they have been prepared within a few minutes of one another; further, the sodium chloride used must be dry and finely powdered. There is considerable saving of time, in carrying out this test, if a number of dilute standard solutions of nitrate are always kept on hand in stoppered bottles.

The most suitable strength of solution for a determination is about 2 parts nitric nitrogen per 100,000, but estimations can be quite well made

* Although we have ourselves used a pipette, it would be much safer to measure out the sulphuric acid and pour it down a small tap funnel with an elongated tube. A little strong sulphuric acid drawn up into the mouth may do irreparable damage, and it is pretty sure to happen some time.

down to 0·25 part. It is very rare for a sample of sewage or effluent, even if it should be absolutely devoid of nitrate, to show nothing at all, no doubt because of the charring action of the strong acid upon minute particles of finely divided organic matter still in the liquid. On the other hand, partially purified turbid effluents containing much dissolved or colloïdal organic matter usually give readings below the correct value as determined by the copper-zinc couple method. We have found, too, that if phosphates are present in excess, they interfere with the test by altering the character of the purple band, the results coming out too low. Want of time has hitherto prevented us from examining such points as this in detail, but we hope to do so later.

If nitrite is present in the liquid tested, a yellow colour is produced in the aqueous layer*, but this does not seriously interfere with the nitrate reading unless it is very intense and in that case standards can be made containing nitrite to the same extent. Such nitrite might also no doubt be oxidized to nitrate before making the determination, but we have not yet been able to test this. We hope to spend some time in trying to increase the accuracy of this method by slightly modifying the apparatus used, etc.

A large number of concurrent estimations of nitrate by this and by the "couple" method have now been made in effluents from bacterial filters, and those comparative results will be available later. But enough has been said to demonstrate the value of this simple process for giving in a few minutes an approximate idea of the amount of nitrate present. The apparatus required, too, is so simple that it can be carried about anywhere.

Note.—It is convenient to have in the laboratory a small leaden tray, large enough to hold a bottle of sulphuric acid and a test tube stand containing a set of tubes, pipettes, etc. If, then, by accident a tube breaks, no harm is done.

Kjeldahl Process for the Estimation of Total Nitrogen and (indirectly) of Total Organic Nitrogen.

The method to be described below gives a determination at one time of the total † nitrogen of a sewage or effluent, or, in all probability, of the total nitrogen, and therefore includes :—

(1) The ammoniacal nitrogen ;

(2) The albuminoid nitrogen ;

(3) The nitrous nitrogen ;

(4) The nitric nitrogen ;

(5) The "X" nitrogen, *i.e.*, that portion of the organic nitrogen which is not included in Nos. 1-4 above. This "X" nitrogen, therefore, represents the difference between the total Kjeldahl nitrogen and the sum of the Nitrogens Nos. 1-4 inclusive. The "albuminoid" and "X" nitrogens, added together, give the total organic nitrogen.

Reagents Required :—

(1) *Nitrogen-free Sulphuric acid.* It is not always easy to get acid which is really (almost) nitrogen-free. Each half-Winchester of acid used must be tested along with the other reagents of a "Kjeldahl" estimation by making two or three "blank" determinations, *i.e.*, determinations for total nitrogen in the reagents alone, as described below. If these blanks should

* This reaction may be made use of to determine *roughly* the amount of nitrite present.

† Cf. p. 30.

come out above a certain limit, say, 0·0004 grm. of nitrogen, then the acid should be tested alone for :—

(a) Ammonia, by distilling, say, 10 c.c. in 200 or 250 c.c. of ammonia-free water with excess of ammonia-free potash and nesslerizing the distillate ;

(b) For nitrites, by *m*-phenylene diamine ;

(c) For nitrates, by the copper-zinc couple, diphenylamine, or other suitable method. If an appreciable quantity of any one of these is found, the acid must be rejected.

(2) *Sugar Solution.*—40 grammes of the purest cane sugar obtainable (small loose crystals, *not* loaf sugar) are dissolved in about 500 c.c. distilled water, and the solution is boiled down in a tinned iron basin with 2 or 3 grammes of stick potash until the volume of the liquid is reduced to about 200 c.c. After cooling, it is made up to about 900 c.c. with pure ammonia-free water and 100 c.c. of nitrogen-free sulphuric acid are added ; when this mixture is quite cold a little more water is added, to make it up to one litre. 5 c.c. of the final solution therefore contain 0·2 grm. sugar and 0·5 c.c. sulphuric acid.

For a long time we did not boil out the sugar with alkali, but afterwards found that it was a distinct advantage to do this, the "blank" being often appreciably reduced as a consequence. The object of adding the sulphuric acid to the sugar solution is of course to prevent the formation of moulds.

(3) *Strong Potash Solution.*—A pound of stick potash is dissolved in about 1½ litres of distilled water in a tinned iron basin,* the solution warmed to near its boiling-point, and sufficient aqueous permanganate of potash introduced in small portions at a time to destroy any organic matter present. The liquid after prolonged evaporation must still show a slight tinge of green manganate when a clean fragment or rod of white porcelain is dipped into it, this small excess of manganate being then finally discharged by the addition of a very little more potash. The solution is evaporated down to about a litre, a little water being *carefully* added (with stirring) from time to time, if required. The amount of permanganate necessary depends, of course, upon the quality of the potash, but each pound of the latter should not require more than about 5 c.c. of saturated aqueous permanganate. The latter is most conveniently added from a pipette, and with a little practice the quantity necessary is arrived at without much trouble. After cooling, the potash solution is siphoned into a Winchester, which should have in it at least two charges of potash ; and it is well to keep two such bottles going, as the manganese mud takes a week or two to settle.† When the supernatant liquid is clear (and colourless), it is again siphoned off into a smaller stock bottle. It is unnecessary to add that such a strong solution of potash requires careful handling.

---

* It is a wise precaution to place the tripod which supports the basin in a shallow earthenware crock of suitable size.

† This manganese mud is free from nitrogen (see Appendix 7).

(4) *Pure Crystallised Sodium Sulphate.*—This is ground up in bulk and any foreign particles are picked out. Properly speaking, it ought to be recrystallised. Before being ground it is tested for sulphites, thiosulphates, and ammonia (by the Nessler reagent), as these impurities are not unfrequently present in objectionable quantities. It must, of course, contain none of them.*

(5) *Pure Zinc Foil.* This is cut into strips weighing 3 grammes each, the size of such a strip being about 10 c.m. by 2·5 c.m. (4 in. by 1 in.). These are then boiled out twice with dilute potash (about 3 per cent.), washed thoroughly with distilled water, dried at once, and kept in a stoppered bottle.

(6) *Approximately Deci-normal Sulphuric Acid.* We always standardise this as Barium sulphate, making at least two estimations.

(7) *Standard Alkali* (either potash or ammonia). This is approximately deci-normal or half deci-normal. The choice of alkali is more or less a personal matter. A solution of ammonia has the advantage of not absorbing carbonic acid to anything like the same extent as potash.

(8) *Sensitive Litmus Solution.* The directions for preparing this with the use of acetic acid and alcohol are to be found in Sutton's "Volumetric Analysis," 7th edition, p. 34.

Method.—100 c.c. of sewage, or 200 c.c. of effluent, are poured into a round-bottomed flask of Jena glass of about 400 c.c. capacity, the neck of which is roughly 12 c.m. long and 2 to 3 c.m. in diameter; 5 c.c. of the sugar solution, 0·5 c.c. nitrogen-free sulphuric acid and a 3-gramme strip of zinc are then added, and the mouth of the flask is covered with a pad of moistened cotton wool interposed between two or more layers of clean filter or tissue paper, the overlapping ends of which are preferably kept tight by a rubber band. The flask is then set aside in a slightly inclined position. A number of such flasks are conveniently placed along a shelf, each one being loosely gripped by a small steel clip screwed on to a horizontal spar of wood. The above method of protecting the liquid was adopted as the result of experience, for it was found that distilled water exposed to the air absorbed very appreciable quantities of ammonia, as much as 0·00003 grm. NH_3 being taken up in a single night by 165 c.c. of water, about 12 m.m. (half an inch) deep, contained in a jar of glazed earthenware.

A further addition of 0·5 c.c. sulphuric acid is made each day until the zinc is entirely dissolved, this usually requiring five days. *The above slow addition of acid and slow reduction are essential*, for we have found that if the reduction of a nitrated effluent is hurried, there will almost certainly be a loss of nitrogen and the estimation will come out too low. The acid in the flask (inclusive of the 0·5 c.c. contained in the added sugar solution) is then made up to 10 c.c. in all, and evaporation on wire gauze over a rose burner or even over a naked flame is commenced (this has, of course, to be done in a draught cupboard, the flask being well inclined). Frothing takes place when nearly all the water has been evaporated off, and hence the flask requires watching at this stage. As soon as bumping begins, the flask is allowed to cool, 8 grammes of the powdered sodium sulphate are added, and the flame is again applied. When the water of crystallization of the sodium salt has been driven off, the acid begins to fume, and the neck of the flask must now

* It would save trouble to add the sodium sulphate in the form of solution, after the liquid in the *Kjeldahl* estimation had been reduced to about 20 c.c., but we have found that this lengthens the process appreciably.

be virtually closed by a small glass balloon which fits fairly closely; heating is then continued until the contents of the flask are colourless, or only faintly yellow, this last stage usually requiring from two to three hours.

After the flask has cooled down, the cake of sulphates is dissolved in distilled water and the solution is transferred to the distilling flask, A (see fig. 2), this latter being also preferably of Jena glass, round-bottomed, and

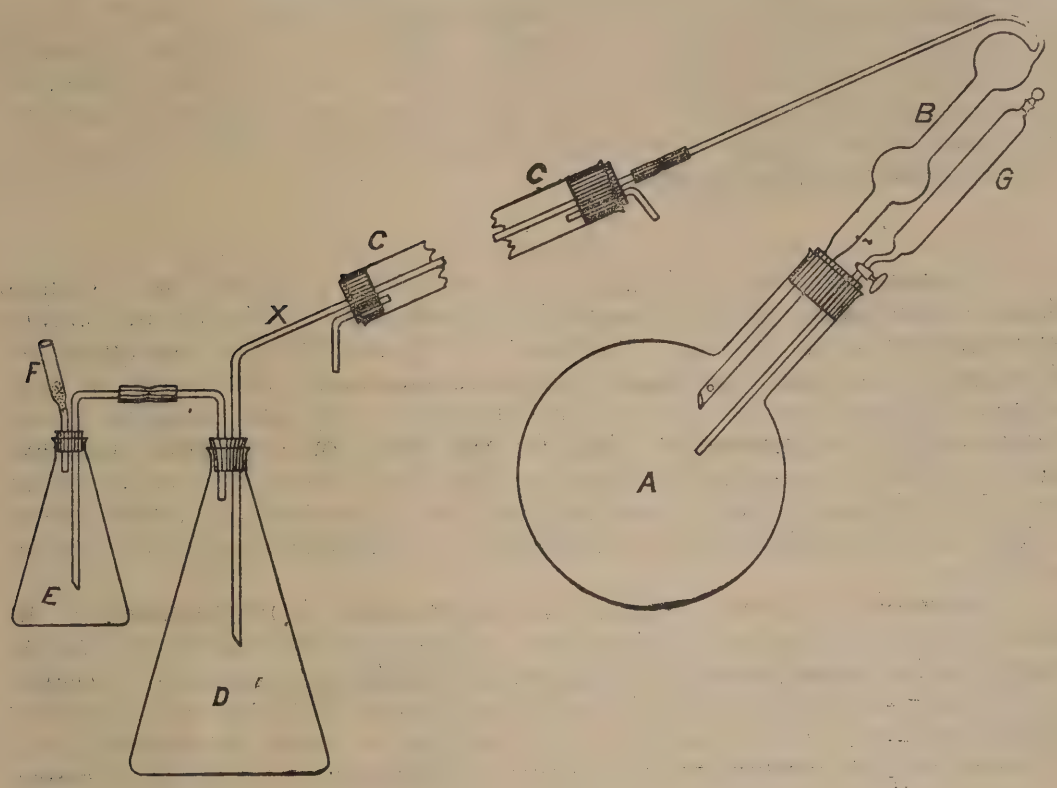


FIGURE 2.

ONE-FOURTH ACTUAL SIZE.

of 750 to 1,000 c.c. capacity. Three or four pieces of wrinkled-up platinum foil* are added, to prevent bumping during the distillation. This flask is then connected by a stout rubber joint to a small Liebig's condenser, C, an anti-spit apparatus, such as a Travers' adapter, B, being interposed between flask and condenser, so as to avoid the possibility of any alkali being carried over mechanically. The inner tube x of the condenser C projects about 15 to 18 c.m. (6 to 7 in.) beyond the lower end of its water jacket, and is bent at such an angle as to be vertical when the condenser is in position. The distillate is collected in the two flasks, D and E (of 500 and 100 c.c. capacity, respectively), fitted together in the usual way by tubes and rubber stoppers, while at the outlet of E there is a small glass tube or tower, F. Tube x is not allowed to dip into the distillate, even at the end of the operation, in order to avoid all chance of the liquid being sucked back into the distilling flask.

Before the receiving flasks are fitted on, an amount of the deci-normal acid, more than sufficient to neutralise all the ammonia in the distillate, is measured into D from a burette, while E receives about 0·5 c.c. and F a few drops, the total volume of acid used being then read off and noted. When all the connections have been made, the requisite excess of purified potash (*i.e.*, about 2 c.c. more than would be required to neutralize 10 c.c. of the nitrogen-free sulphuric acid) is run into A through a long tap funnel G, which is then rinsed with a little water, and distillation is carried on

* For a long time we used fragments of granulated zinc for this purpose. But there must have been a little hydrogen produced by the action of this zinc on the dilute alkaline solution in the distilling flask, and this hydrogen would exert a reducing action upon any traces of nitrate present in the permanganated potash. A minute error might thus be introduced into the estimation, though of course the conditions when distilling both estimation and blank were as nearly as possible the same.

until bumping commences. At this stage about 30 c.c. of pure distilled water are run in, and distillation is continued until the flask begins to bump again, when the operation is stopped. The whole distillation takes from three-quarters of an hour to one hour; we find it a distinct advantage, as regards time, to wrap cotton wool round the neck of the flask and the adapter (see figure), but this must not be placed sufficiently near the flame to catch fire.

The contents of F and E are now rinsed into the larger Flask D, and a few drops of litmus solution are added. The carbon dioxide present is then boiled off, the flask cooled in water, and the residual acid determined by titration with the standard alkali in the ordinary way. A simple calculation then suffices to give the ammonia found in terms of *Total Nitrogen* per 100,000 parts of sewage or effluent.

"*Blanks.*"

As already indicated on p. 24, it is necessary to make two or three blank experiments for each set of reagents, using 200 c.c. of distilled water in place of the sewage or effluent. In those "blanks" the quantities of reagents used and the whole procedure—including the length of time occupied in dissolving the zinc—should be exactly the same as given above. Occasionally, when pressed for time for the figure of a "blank," we have quickened the process, the tendency has been for the result to come out too low.* The volume of deci-normal acid required to neutralise the distillate of a blank estimation should not exceed 0·2 c.c.; we have, in fact, had it as low as 0·11 c.c.

A part of the above "blank" no doubt comes from the alkali of the upper heated portion of the glass tube *x* through which the water distils; hence it is important to shorten the time of distillation as much as possible, *e.g.*, by using a thin condensing tube of hard glass, which allows of quicker distillation than a thick one does. At one time we made experiments with a silvered copper distilling tube, bent into the adapter shape (Fig. 3), instead

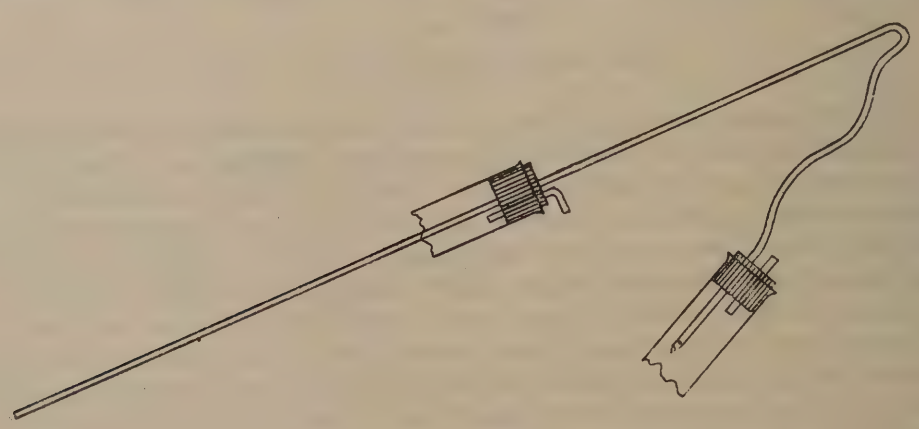


FIGURE 3.

ONE-FOURTH ACTUAL SIZE.

of a glass one. The earlier results were good, but the silver soon began to wear off. Probably a tube of pure silver would answer very well, and we intend to try this shortly.† A very small part of the "blank" also no doubt arises from the solvent action of the slightly acid liquid upon the glass of Flask D, when carbonic acid is being boiled off towards the end of the titration.

The use of sugar as an additional reducing agent to the zinc foil was determined upon after a considerable amount of time had been spent in experimenting with other substances usually recommended for this purpose, *e.g.*, zinc dust,‡ salicylic acid, etc.; but we found that the "blanks" given

* Thus, a slow "blank" done upon reagents which were not very pure, gave nitrogen equivalent to 0·45 c.c. standard acid, while a "quick" blank showed only the equivalent of 0·29 c.c. (Cf. Reduction of Nitrates, p 31.)

† Since the foregoing was written, we have obtained the following blanks with the same set of reagents:—

Silver tube: 0·08 c.c. and 0·08 c.c. acid = 0·00011 grm. nitrogen.
Glass tube: 0·14 c.c. and 0·12 c.c. acid = 0·00019 grm. nitrogen.

‡ For a few comparative blanks with zinc dust, etc., Cf. Appendix 7 (2).

by these latter were much too large for this delicate nitrogen determination Since that time the use of sugar has been continued in order to ensure uniformity in testing a large number of samples, and also in case there should ever be present some substance not reducible by zinc and acid alone. But the following series of duplicate determinations of the total nitrogen in various kinds of effluents, *with and without sugar*, by the same experimenter, appear to show that reduction with zinc and acid alone is sufficient. No such duplicate determinations have yet been done with sewages and tank liquors.

No. of Sample.	Nature of Sample.	Nitrogen—Parts per 100,000.		Difference.
		With Sugar.	Without Sugar.	
No. 159	3rd Field effluent.	1·88	1·54	−0·34
168	Final filtration effluent.	0·64	0·60	−0·04
169	Final irrigation effluent.	1·30	1·48	+0·18
183	1st Field effluent.	9·36	9·38	+0·02
185A	1st Field effluent	10·11	10·32	+0·21
187B	1st Field effluent.	8·08	8·13	+0·05
188	1st Field effluent.	6·92	6·88	+0·04
189C	2nd Field effluent.	6·22	6·26	+0·04
192	2nd Field effluent.	5·63	5·61	−0·02
199	1st Field effluent.	4·90	4·53	−0·37
204	General filtration effluent.	1·91	1·90	−0·01
205	General filtration effluent.	1·82	1·80	−0·02
205C	Filtration effluent.	1·51	1·52	+0·01
207	Filtration effluent.	2·82	2·78	−0·04
209	Filtration effluent.	1·90	1·90	±0·0

It will be seen from this table that the total quantity of nitrogen in the above effluents varied between 0·60 and 10·32 parts per 100,000, —a wide range; further, much of the nitrogen was in the form of nitrate (*cf.* the various tables of analysis of the Report on the Land

Treatment of Sewage, Part II.)*. In eleven of the above fifteen duplicate estimations the difference is only in the second decimal figure, and never above 0·05; in the other four cases, whether owing to errors of sampling or of analysis, the agreement is not so good. But the foregoing figures are sufficient to prove the consistency of the results obtained by this modification of the *Kjeldahl* method, while at the same time they indicate that the use of the sugar solution might possibly be dispensed with in the case of effluents. One advantage of not using sugar is that the time required in the final heating of the sulphates in the Kjeldahl flask is shortened, and this of course lessens any possible chance of traces of ammonium sulphate being carried away mechanically by the escaping sulphuric acid fumes. On the other hand, an effluent might conceivably, though not probably, contain a nitrogenous compound not reducible by zinc and acid alone (*cf.* Dyer, *Journ. Chem. Soc.* for 1895, p. 811). In the paper just cited, Dyer gives a very full list of substances which yield up all their nitrogen under the Kjeldahl process which he followed. Putting everything together, we think it may be safely assumed that our modification of the Kjeldahl method does really estimate the whole of the nitrogen present in a sewage or an effluent.

To test the effect of different methods of heating the Kjeldahl flask, the following duplicate estimations were also done by the same experimenter, sugar being used in every case.

No. of Sample.	Nature of Sample.	Nitrogen—Parts per 100,000.		
		Evaporation and subsequent heating on sand-bath.	Evaporation and subsequent heating on wire gauze.	Difference.
212	Filtration effluent.	1·46	1·50	+ 0·04
			Evaporation and subsequent heating over naked flame of rose burner.	
211	do.	1·64	1·67	+ 0·03
213	Dilute sewage.	1·45	1·40	— 0·05
214	Filtration effluent.	2·59	2·70	+ 0·11
214b	do.	3·21	3·17	— 0·04
217	Sewage.	11·63	11·41	— 0·22
218	Filtration effluent.	1·62	1·59	— 0·03
220	do.	2·62	2·53	— 0·09

Here again it will be seen that the results are very consistent, and that any one of the above methods of heating may be employed. It is however best, on the whole, to heat the flask on wire gauze over a rose-burner flame. But it must not be forgotten that at certain stages of the heating the flask has to be carefully watched.

* Part II., Chemical Report, by Dr. G. McGowan.

A further duplicate estimation with different quantities of zinc gave :—

No. of Sample.	Nature of Sample.	1·5 grms. Zinc +Sugar Solution.	3 grms. Zinc +Sugar Solution.	
221	Filtration effluent.	2·43	2·46	+·03

In this case, therefore, the smaller quantity of zinc was sufficient, but the nitric + nitrous nitrogen in the effluent amounted to only 0·72 part per 100,000.

Estimation of Nitrates by the above Kjeldahl Method.

With regard to the estimation of *Nitric Nitrogen* by this Kjeldahl method—when the zinc is dissolved rapidly by adding the whole 10 c.c. of sulphuric acid at once, the reduction of nitrate to ammonia is very incomplete ; this is proved by the following two determinations made with a solution of pure potassium nitrate :—

	I.	II.
Nitric Nitrogen taken (grms.) - -	0·008078	0·005993
Nitrogen found by Kjeldahl (grms) -	0·006152	0·004260
Loss - - - -	0·001926	0·001733
Percentage loss - -	23·8	28·9

But when the slow reduction method is followed with solutions of pure potassium nitrate, the error does not exceed about 3 per cent. of the total quantity taken, as is shown by the following three estimations :—

	Grms. Nitric Nitrogen taken in 200 c.c. Distilled Water.	Equal to Parts Nitric Nitrogen per 100,000.	Nitrogen found by "Kjeldahl."	Loss.	Percentage Loss.
I.	0·011821	6·01	0·011543	0·000278	2·4
II.	0·011633	5·81	0·011226	0·000407	3·5
III.	0·011633	5·81	0·011190	0·000403	3·5

In order to see whether a closer approximation (than the foregoing error of 3 per cent.) to the estimation of the nitric nitrogen in a solution of pure potassium nitrate could be obtained by using aluminium foil and caustic potash for reduction, instead of zinc and acid, a few experiments were made as follows :—

From 0·5 to 1·0 grm. aluminium foil and 10 c.c. of the purified potash were used for each estimation, which was made in a tightly-corked flask fitted with a valve containing a little dilute sulphuric acid, so as to trap

any ammonia that might escape from the alkaline liquid. After reduction the whole was boiled down with strong sulphuric acid in the usual way, no sodium sulphate being however added. The results showed a loss of 6 to 12 per cent. of nitric nitrogen upon quantities of 0·006 grm. nitric nitrogen in 100 c.c. of liquid.

There was also the further objection that the cake of aluminium sulphate did not dissolve in the boiling sulphuric acid during the last stages of heating, and hence it was practically impossible to disintegrate all the carbonaceous (and nitrogenous ?) matter.

The loss per cent. would, of course, be smaller in a solution containing nitrogen in the form of ammonium salt as well as of nitrate (assuming that no compound of nitrogen is present which escapes reduction). Thus, with solutions containing ammonium chloride alone, the Kjeldahl method gave the following results :—

Parts per 100,000.			
Ammoniacal Nitrogen taken (presumably in 200 c.c. water).	Nitrogen found by "Kjeldahl."	Gain or Loss.	Percentage Gain or Loss.
I. 4·117	4·121	+0·004	+0·10
II. 2·061	(a) 2·133 } Two determinations (b) 2·065 }	+0·072 +0·004	+3·5 +0·19
III. 2·061	2·045	−0·016	−0·78

Rejecting II. (a) as being probably a bad estimation, the other figures found are very near those required by theory.

Estimation of Nitrites by the above Kjeldahl Method.

The following mixed solutions (each in 200 c.c. distilled water), which consisted mainly of salts of ammonium together with very considerable quantities of nitrite, but very little nitrate, gave :—

Parts per 100,000.						
Nitrogen taken as :			Total Nitrogen taken.	Nitrogen found by "Kjeldahl."	Gain or Loss.	Percentage Gain or Loss.
Ammonium Chloride.	Potassium Nitrite.	Potassium Nitrate.				
2·061	0·038	0·005	2·104	2·181	+ 0·077	+ 3·7
2·061	0·383	0·049	2·493	2·526	+ 0·033	+ 1·3
1·095	0·076	0·004	1·175	1·205	+ 0·030	+ 2·6
1·095	0·152	0·007	1·254	1·225	− 0·029	− 2·3
2·061	0·383	0·049	2·493	2·474	+ 0·019	− 0·8

These results prove that amounts of nitrous nitrogen, such as are usually found in sewage effluents, are estimated—within the limits of experimental error—by this slow-reduction Kjeldahl process. The following figures, however, show that this is not the case with solutions containing large amounts of nitrous nitrogen (3 to 4 parts per 100,000), quantities far in excess of any that we have ever found in land effluents, or indeed in any sewage effluent with possibly only one exception :—

Parts per 100,000.

Nitrogen taken as :		Total Nitrogen taken.	Nitrogen found by "Kjeldahl."	Loss.	Percentage Loss.
Potassium Nitrite.	Potassium Nitrate.				
3·832	0·488	4·320	3·460	0·860	22·5
2·980	1·830	4·810	3·990	0·820	27·4

This loss is doubtless caused by lower oxides of nitrogen escaping from the acid liquid before the nascent hydrogen has had time to reduce them. It would therefore be advisable, when a Kjeldahl estimation has to be made of a solution containing a great deal of nitrite, to first convert that nitrite into nitrate by means of pure permanganate solution.

Conclusion.—To sum up shortly : This slow reduction Kjeldahl method, if carried out in the manner detailed above, is excellent for arriving *directly* at the total nitrogen in a sewage, tank or precipitation liquor, or effluent. It is also to be recommended for the *indirect* determination of the "X" nitrogen and the total organic nitrogen in sewages, tank or precipitation liquors, and (with care) in effluents of average quality. But with very pure effluents, such as those from the Nottingham sewage farm (whose nitrogen is present almost altogether as nitrate), the errors of experiment are too great for this indirect method for the determination of "X" nitrogen and total organic nitrogen to be of value at present, though the method could no doubt be still further refined (*cf.* tables of analysis).* When once the details of the process have been mastered, it does not require a disproportionate amount of time to carry it out. And we think that there can be no doubt of its value, both for the actual information which it gives of the composition of the liquid in question and because of its acting as a check upon the other figures of analysis. It has, of course, the drawback of being an *indirect* method as regards "X" nitrogen and total organic nitrogen. It was intended to have made a considerable number of comparative estimations of organic nitrogen in this way, and also by the well-known direct method of Frankland and Armstrong, but time has so far not allowed of sufficient being done to warrant any conclusions. We hope, however, to be able to do this later.

Correction for Nitrite in the earlier Kjeldahl Estimations of Total Nitrogen in the Land Samples.

In the earlier Kjeldahl estimations, up to sample No. 226c, attempts were (mistakenly) made to decompose any nitrite present in the quantity of

* Part II., Chemical Report, by Dr. G. McGowan.

sewage or effluent taken, before reducing the solution with zinc. The method adopted was to heat the 100 c.c. or 200 c.c. of liquid to boiling in a Kjeldahl flask after the first addition of 0·5 c.c. sulphuric acid alone, or after the addition of this acid together with the 5 c.c. of acid sugar solution. Some very early experiments had led to the belief that this procedure would decompose either the whole or nearly the whole of the nitrite present in solution. But this was not borne out by subsequent observations, and hence a series of determinations had to be made, in order to apply the necessary correction—in most cases a very small correction—to some of the Kjeldahl results.

The plan followed here was to dilute to 200 c.c. with distilled water known amounts of pure potassium nitrite solution (previously standardized by permanganate) and, after the addition of 0·5 c.c. sulphuric acid, or 0·5 c.c. acid plus 5 c.c. of the sugar solution, to heat to incipient ebullition in a Kjeldahl flask over a rose-burner flame. The nitrite remaining undecomposed was then determined by *m*-phenylene-diamine.

The results obtained by treating with acid alone were not sensibly different from those with acid and sugar solution; nor did the presence or absence of ammonium salts—added as ammonium chloride—appreciably influence the percentage amount of nitrite decomposed. It was further ascertained by experiment that there was no reduction of nitrate to nitrite by heating to boiling with the acid sugar solution. The figures obtained are briefly summarised in the following table :—

Nitrous Nitrogen taken in 200 c.c. of liquid, expressed in Parts per 100,000.	Number of Observations made.	Mean percentage amount of Nitrous Nitrogen left in the Solution.	
			Extremes.
0·02	5	43·1	(27·2—54·0)
0·04	5	46·2	(36·9—60·0)
0·08	5	54·2	(36·9—60 7)
0·11	8	45·4	(26·7—57·8)
0·15	2	50·4	(47·2—53·5)
0·22	2	42·2	(39·7—44·7)
0·25	2	51·2	(49·3—53·0)
0·32	2	49·0	(44·5—53·5)
0·43	3	55·7	(50·5—62·3)
0.54	4	48·2	(36·2—63·8)
0·67	2	46·6	(45·2—48·0)

It was found impracticable to arrive at this nitrite correction *directly* by the Kjeldahl process alone, *i.e.*, by making two determinations of total nitrogen in the same sample (a) without any preliminary treatment, and (b) after raising to the boiling point with acid, as above. The amounts of nitrous nitrogen present in most of the land samples were less—usually much less—than 0·15 part per 100,000, and the Kjeldahl error of experiment was too large in proportion to this to allow of correct deductions being drawn.

Experiments upon the Determination of Organic Nitrogen by the Kjeldahl Process without reduction, conjoined, where possible, with the direct determination of free and saline ammonia.

We have made a considerable number of concurrent determinations of the organic nitrogen of sewages, effluents, etc., by this method, and by the method *with* reduction which has just been described, but although in some instances the method without reduction gave the better results, we have found it on the whole much less reliable. The process adopted was as follows :—

From 10 c.c. to 100 c.c. of the sample (according to its strength) were boiled down with 4 c.c. of nitrogen-free sulphuric acid in a round-bottomed Jena flask, the heating being continued, after all the water had been evaporated off, until the acid became colourless (the mouth of the flask was closed by a small glass balloon as soon as the acid began to fume). When cold, the flask was rinsed out with distilled water into a stoppered measuring flask of known capacity, a few c.c. of a solution of oxalate of potash (ammonia-free) being sometimes added, to throw down the lime present. The solution was then rendered *just* alkaline with purified potash, before being made up to the mark with water.

The flocculent precipitate which invariably formed upon the addition of the potash, both in the presence and absence of oxalate, was allowed to subside for at least 24 hours, and a suitable fraction of the clear liquid was then nesslerized.

A "blank" was made in exactly the same way, using like quantities of reagents, but substituting distilled water for the sewage or effluent. The nitrogen found in the "blank" had then only to be corrected for the minute quantity of nitrogen in the distilled water added before boiling down. The resulting figure, representing the unoxidized nitrogen in the 4 c.c. of sulphuric acid used, was then subtracted from the corresponding one in the actual estimation, the difference giving the organic nitrogen plus the nitrogen from the free and saline ammonia present. By deducting the latter, determined if possible by direct nesslerization of the sample, a value was obtained for the organic nitrogen present. As will be seen, however, by a reference to the Chemical Tables of Analysis in the Land Report,* direct nesslerization for free and saline ammonia was more often than not impossible, owing to the turbidity produced on adding the Nessler reagent.

There are several objections to this method of estimation, viz :—

(1) A turbidity is frequently produced on the addition of the Nessler reagent, even after lime salts have been precipitated by oxalate ;

(2) The nitrogen of the free and saline ammonia, plus the organic nitrogen, determined as above, have in many cases come out lower than the figure for free and saline ammonia alone, whether the latter has been estimated directly or by distillation. This last appears to be more or less due to the presence of nitric nitrogen, the greatest discrepancies being usually obtained with highly nitrated samples, though this was not invariably the case.

* Part II., Chemical Report, by Dr G. McGowan.

In order to gain some light on the point, experiments were made upon the evaporation of dilute solutions of pure potassium nitrate with the usual quantity (4 c.c.) of nitrogen-free sulphuric acid, the evaporation being stopped at different stages; the nitrogen left behind was then determined by the copper-zinc couple method. The results are shown in the following table :—

Grms. Nitric Nitrogen in 100 c.c. Distilled Water (+4 c.c. Acid).	Equal to Parts Nitric Nitrogen per 100,000.	Per Cent. of Water Evaporated off.	Grms. Nitric Nitrogen left in Residue.	Per Cent. Nitric Nitrogen left in Residue.
0·010	10·0	58·1	0·01029	100·0
0·002	2·0	83·0	0·00203	100·0
0·002	2·0	93·5	0·00161	80·7
0·002	2·0	98·0	0·00094	46·9
0·002	2·0	99·0*	0·00033	16·4

* This was fuming slightly.

It is thus clear that the greater part of the nitric nitrogen persists in the sulphuric acid solution until shortly before the latter begins to fume. The free nitric acid, which is then, of course, concentrated, must exert an oxidizing action upon any organic matter present, some of the organic nitrogen being then probably lost in the form of lower oxides of nitrogen.

(3) There is probably some absorption (or adsorption) of ammonia by the precipitate produced in the alkaline liquid, as is shown by the following figures. These were obtained by (1) pipetting off most of the clear liquid and nesslerizing 10 c.c. of it directly; (2) shaking up the precipitate in the remaining liquid, withdrawing 10 c.c. of the mixture, distilling and nesslerizing. (Strictly speaking, this comparison would have been a more correct one if *both* the clear and the turbid liquids had been distilled before being nesslerized.)

Number of Sample.	Nature of Sample.	Organic Nitrogen; Parts per 100,000.	
		Clear Liquid.	Turbid Liquid.
168	Final Filtration Effluent.	0·19	0·41
172	Final Surface Effluent.	1·38	1·49
173	Do. Do	0·72	0·81
182	Street Washings.	0·66	0·80

Oxalate was used in the case of Nos. 172 and 182, and possibly in the others also, but there are no records with regard to the latter.

The above differences would be slightly augmented, were a correction to be introduced for the volume of the precipitate.

To conclude: If the Tables of Analysis* be referred to, it will be seen that in many of the sewages examined the results obtained for organic nitrogen by this method *without* reduction agreed very well with the figures by the other method. Again, in samples containing an appreciable amount of organic nitrogen and not more than, say, 0·5 part of nitric nitrogen per 100,000—conditions frequently met with in brook water receiving effluent—the organic nitrogen found by the method without reduction evidently approximated in most cases to the truth. In very pure effluents, too, the method, even with the drawbacks mentioned, frequently gives results which are more nearly correct than the method *with* reduction. But, for general work upon sewages and sewage effluents, our experience is against the method *without* reduction, for the reasons just stated.

"Oxygen Absorbed" from a solution of Acid Permanganate at 26·7°C. (80°F.):—(a) At once; (b) after four hours.

The principle of this well-known test is sufficiently explained by its title.

Solutions Required.

(1) *Aqueous potassium permanganate*, containing 3·94 grammes per litre.

(2) 10 *per cent. sulphuric acid, i.e.*, 90 vols. water and 10 vols. concentrated acid.

(3) *Sodium thiosulphate*, containing about 12 grammes of the salt and 2 grammes of sodium carbonate per litre.

The oxygen value of this thiosulphate is determined by means of decinormal bichromate solution (prepared from the re-crystallised and pure salt), potassium iodide and hydrochloric acid, as given in Sutton's "Volumetric Analysis," 7th edition, p. 131. This value should of course be frequently checked, as the solution tends to weaken with time; and, for the same reason, its equivalent of permanganate should be determined for each day that it is used.

(4) *A dilute and clear solution of Starch.* This must not contain any floating particles.

Process.—(a) The "At Once" Test.—10 c.c. of the permanganate solution are measured out by means of a pipette into a small stoppered bottle of about 100 c.c. capacity, an equal volume of the dilute sulphuric acid is added to it, and the bottle containing the mixture is carefully warmed *in* a water bath to a temperature of 26·7°C. (80° F.). A portion of the sample of sewage or effluent is warmed separately to the same temperature, and 25 c.c. of it (or 10 c.c., diluted to 25 c.c. with distilled water, in the case of a very strong sewage) are added to the acid permanganate. The contents of the bottle are mixed by gentle rotation, and the unreduced permanganate is determined *at once* by the addition of a few white crystals of potassium iodide and titration of the liberated iodine with the standard thiosulphate, a few c.c. of dilute starch solution being added towards the end of the reaction.

The time required from the mixing of the warmed sewage or effluent with the warmed acid permanganate to the addition of the potassium iodide is about half a minute.

---

* Part II., Chemical Report, by Dr. G. McGowan.

Probably the "3 minutes" test, which is commonly followed, is better than the above "at once" test, since the former gives rather more time for the reaction to complete itself. But as we had got into the habit of carrying out the test "at once," it was thought well to continue it in this way for purposes of comparison.

The following Table gives a number of comparative estimations made "at once," and "after 3 minutes" at 26·7° C. (80° F.), the above strong permanganate solution being used in both cases :—

No. of Sample.	Nature of Sample.	Strong Permanganate Solution at 26·7° C. (80° F.)		
		At once.	After 3 minutes.	After 4 hours.
3381	Storm water.	1·20	1·88	7·77
3385	,,	1·29	1·50	5·22
3370	Crude sewage.	7·20	10·31	27·57
3375	,, (weak.)	0·46	0·53	1·62
3378	,,	4·40	4·93	20·21
"A" (Caterham)	Crude sewage.	7·20	9·03	23·59
3384	,,	1·13	1·57	6·54
3394	Settled sewage.	3·73	4·53	11·81
3368	,,	3·68	5·56	16·82
3371	,,	4·51	6·45	17·24
3377	,,	3·04	4·04	11·34
3390	,,	1·35	1·43	4·32
"B" (Caterham)	Septic tank liquor.	4·06	5·31	18·01
Ilford	,,	0·64	0·74	2·84
3395	,,	1·56	2·32	6·79
3404A	,,	4·68	5·81	9·82
664	Precipitation liquor.	0·63	0·90	3·69
3385A	,,	1·23	1·40	5·75

No. of Sample.	Nature of Sample.	Strong Permanganate Solution at 26·7°C. (80° F.)		
		At once.	After 3 minutes.	After 4 hours.
3389	Contact effluent. Primary.	0·69	1·00	3·67
3393	,,	1·20	1·38	3·96
3398	,,	0·59	0·92	2·67
3379	,,	0·11	0·17	0·81
3360	,,	0·32	0·52	1·51
3360 B	,,	0.32	0·49	1·42
3388	Secondary	0·41	0·55	0·77
3387	,,	0·26	0·33	1·00
3391	,,	0·46	0·56	1·94
663	Tertiary	0·38	0·46	0·97
"A"	Continuous effluent	0·79	0·86	2·56
"A_1"	,,	0·77	0·94	3·68
3386 B	,,	0·23	0·35	0·67
3392	,,	0·39	0·46	1·61
"B"	,,	0·64	0·80	2·37
3366	,	0·19	0·22	1·05
3369	,,	0·31	0·32	1·12
3373	,,	0·36	0·35	1·19
3376	,,	0·29	0·30	1·00
"C"	,,	1·31	1·41	3·76
"D"	,,	1·13	1·16	2·93
3380	,,	0·19	0·37	1·53
3397	,,	0·45	0·57	1·64
3382	,,	0·14	0·26	1 14

From these Tables it is seen that the ratios of the two tests, *at once* and *after three minutes*, when done with strong permanganate at 80° F. are :—

For 10 sewages and 2 storm waters	...	1 : 1·32
„ 4 septic tank liquors	...	1 : 1·30
„ 6 primary contact bed effluents	...	1 : 1·40
„ 3 secondary and one tertiary effluent	...	1 : 1·26
„ 9 continuous filter effluents* ...	...	1 : 1·26

*(Omitting the continuous effluents with the high figures.)

Further estimations are required here, but apparently the average ratio for final contact and continuous filter effluents of a fair degree of purity is about 1 : 1·25 ; and the higher the degree of purity, the less marked is the difference between the two tests.

The four hours Test.—A similar determination to the above is made with similar volumes of sample and acid permanganate, after the mixture has been allowed to stand in an incubator at 26·7° C. (80° F°.) for four hours†.

In both cases the results are expressed in terms of "*Oxygen absorbed*" from permanganate per 100,000 parts of the sample by weight.

A few minutes longer or shorter in carrying out the "4 hours" test makes practically no difference in the results obtained; but unless the "at once" determination is made within certain prescribed limits of time, the figures may show a marked divergence. Several such (more or less) discrepant results, probably arising chiefly from this cause, are given in the Tables of Analysis of the Leicester Sewage Farm (Samples No. 124, 126, 128, 130 and 131‡).

As a general rule the permanganate solution used by chemists for sewage and effluent analyses is only one-tenth as strong as that given above, and there are no doubt advantages to be claimed for both strengths. We think that for dealing with a variety of sewages and tank liquors of very different concentrations the strong permanganate is to be preferred. For effluents, however, unless they are very impure, and assuming that there is always a large excess of permanganate present, the weak solution no doubt gives more accurate results, the error of analysis being rather less in this case.

Since sewages, tank liquors, and certain effluents contain organic sediment as well as organic matter in solution, it would probably be well to gently rotate the bottle in which the four hours' mixture is being warmed, at, say, half time, in case there might be any deficiency of permanganate in the liquid then in immediate contact with this sediment. We ourselves have not done this, but it is recommended for the weak solution by Mr. Fowler in his "Sewage Works Analyses." Of course, in using a strong permanganate solution (of which never less than 50 per cent. should remain unacted upon at the end of the four hours), any danger arising from this cause is likely to be very slight. We would again emphasise the desirability of always having a large excess of permanganate present, whether the weak or the strong solution be used.

We have not yet made a sufficient number of *comparative estimations with the weak and strong permanganate solutions* to be able to comment with advantage upon the point at this stage. But it is evident that the action of the strong permanganate at 80°F. is markedly greater than that of the weak permanganate at 60° or 65°F. Speaking provisionally, the ratio-figures appear to be, *roughly* :—

	Weak Permanganate at 65°F. ; 3 mins.	Strong Permanganate at 80°F. ; at once.
(A) - - - -	1·0	1·1.

† The incubator used should not be too small. During the Land investigation the incubator employed was an ordinary steam oven, with a piece of asbestos or paper cardboard inside the door, and the variations of temperature were occasionally greater than they should have been.

‡ Part II., Chemical Report, by Dr. G. McGowan.

So far as our results go, this ratio seems to be very constant for sewages, septic tank liquors and precipitation liquors, but much more irregular for effluents from artifical processes (we have no data on the subject with regard to effluents from land).

	Weak Permanganate at 65°F. ; 4 Hours.	Strong Permanganate at 80°F. ; 4 Hours.
(B) - - - - -	1·0	1·6.

This second ratio appears to be fairly regular throughout, for all the above classes of liquid (again without reference to land effluents). The subject will be dealt with in a subsequent paper, and at the same time *the relation between the "oxygen absorbed" from permanganate and the dissolved oxygen taken up from water* will be discussed ; a large number of data on this latter point are being accumulated.

Addendum.—One experiment was made on November 10th, 1899, in order to see whether the atmospheric oxygen present in the upper portion of the bottle took part to any measurable extent in the 4 hours' oxidation at 80° F., by performing the test in duplicate (a) in the ordinary way ; and (b) in a bottle filled up to the stopper with distilled water, only a minute air-bubble being left. As was to be expected, the results agreed closely, *i.e.*, the atmospheric oxygen exerted no appreciable influence.

Incubator Test (by Permanganate).

This has been carried out, as recommended by Mr. Scudder (for the "3 minutes" test), as follows :—

A small well-stoppered bottle (of about 125 c.c. capacity) is completely filled with effluent, the stopper firmly inserted, and the liquid incubated at a temperature of 26·7° C. (80° F.) for five days. At the end of this time the oxygen absorbed" from permanganate *at once* is again determined. If either the same quantity of permanganate or less of it is now required than in the corresponding estimation in the original sample, the liquid has withstood incubation ; if, on the other hand, more is needed, it has not.* In working out the quantities of permanganate oxygen thus used, allowance must be made for the nitrite present ; *i.e.*, the amount of oxygen equivalent to the nitrous nitrogen in the solution at the time of the thiosulphate titration is deducted from the total permanganate oxygen used up. The reason for this of course is that, although nitrites are themselves readily oxidized by permanganate, they are on the other hand oxidizing agents as regards organic matter generally.

A considerable number of comparative estimations were also made of the 4 *hours* permanganate used up before and after incubation, which are to be found in the Tables of Analysis.† These have not been reckoned out further, but a reference to the various Tables will show that this double 4 *hours* test runs in the main parallel with the double test *at once.*

Incubator Test (by Smell).

A much simpler form of incubator test than the above consists in merely noting the appearance and smell of the liquid after incubation. If the sediment has become dark coloured (from the formation of sulphide of iron), the smell is invariably putrid, whereas if it remains brownish-red, the liquid is usually quite inoffensive. We have found that these two tests—Mr. Scudder's and the smell test—run for the most part together in the case of land effluents, especially if one allows a little margin on either side of the permanganate figure for experimental error. On the whole, the permanganate incubator test is the more stringent of the two.

* *Cf.* Fowler, *Sewage Works Analyses*, p. 35.
† Part II., Chemical Report, by Dr. G. McGowan.

Occasionally, though not often, a case arises where the characterisation of the smell is for one reason or another difficult, this being not infrequent when nitrite in considerable quantity is produced during the incubation. Doubtful cases can, however, often be resolved by testing the air in the upper part of an incubation bottle, after shaking up the liquid, with a strip of *slightly* moistened acetate of lead paper. On the whole this test—a very severe one—is of great practical value because of its simplicity.

We have not actually carried out *Mr. Stoddart's Modification of the Incubator Test** (depending on the determination of sulphuretted hydrogen after incubation), and cannot therefore offer any opinion with regard to it.

NOTE.—In the Tables of Analysis† a few instances are recorded, which show that five days' incubation at 80° F. is not necessarily sufficient to indicate offensive putrefaction, an effluent occasionally remaining sweet for five days, but becoming bad if incubated for a longer period. But, for all practical purposes, five days may be taken as long enough.

DETERMINATION OF COMBINED CHLORINE.

Solutions required $\left(\text{these are approximately } \frac{N}{35}\right)$:—

(1) *Silver Nitrate.*—4·79 grms. of the dry crystallized salt per litre. 1 c.c. of this solution is equivalent to 0·001 grm. chlorine.

(2) *Sodium Chloride.*—1·648 grms. of the pure dry salt per litre. 1 c.c. = 0·001 grm. chlorine.

This sodium chloride is conveniently prepared by making a strong solution of ordinary table salt, allowing this to stand overnight, and then filtering it clear. Hydrochloric acid gas (from salt and sulphuric acid) is then passed into the aqueous solution through a tube which is not too narrow, and which is widened to a kind of small funnel at the end which dips into the salt solution. As the latter becomes acid, sodium chloride begins to crystallize out in small crystals. The magma thus obtained is drained by the pump through a funnel stopped by a platinum cone, washed once or twice with small quantities of water, and finally ignited gently in a platinum basin.

(3) *Neutral Chromate of Potash* (K_2CrO_4).—A fairly saturated solution of this is used.

The silver nitrate solution is first standardized against the solution of sodium chloride, using the chromate as indicator. A number of such estimations made with two different silver solutions against new standard sodium chloride on October 6th, 1902, gave results practically agreeing with one another, the average value of 1 c.c. of silver nitrate, in terms of chlorine, being 0·000995 grm. (instead of 0·001 grm.). More often than not, in fact, the silver nitrate has been taken as pure and dry, and its solution not standardized against the chloride, though this is not really a desirable thing to do.

Process.—In an actual estimation 50 c.c. of the filtered sewage or effluent are evaporated‡ down to a volume of 1 or 2 c.c. (or even to

* *Analyst*, vol. XXVI., p. 281 (1901).

† Part II., Chemical Report, by Dr. McGowan.

‡ This evaporation must be done in a draught cupboard, to prevent the escape of ammonia into the air of the room.

dryness, if the titration has to be delayed), in a porcelain basin on the water bath. Three or four drops of the chromate solution are added to this residue, which is then titrated with the solution of silver nitrate under constant stirring, the end of the reaction being marked by the persistence of the colour of the orange-red silver chromate. We have adopted this plan of evaporation before titration because, when working with a pure dilute solution of sodium chloride, it was found that more than the theoretical quantity of silver nitrate had to be added before the indicator marked the end of the reaction, this excess being greater with high dilutions of the chloride.* It is thus desirable that the volume of the chloride solution to be titrated shall not exceed one and a half times the volume of the silver nitrate required, if this excess is to be avoided. It would not of course do to evaporate an acid sewage or effluent without first rendering it slightly, but distinctly, alkaline with a solution of pure bicarbonate of lime or carbonate of soda, neutralizing in the case of the sodium salt any excess of alkali with nitric acid after the evaporation and charring.

The organic matter in a filtered sewage, tank liquor, or effluent must exert some slight reducing action upon the silver solution used, and to get an absolutely correct estimation of the chlorine present would necessitate the destruction of all organic matter. In actual practice, however, this has been found to be unnecessary. To ascertain the extent to which the results are affected by the organic matter, a number of comparative estimations of chlorine have been made in different ways, of which the following may be cited :—

Number of Sample.	Nature of Sample.	Estimation Gravimetrically as Silver Chloride.	Direct Titration without Evaporation.	Direct Titration after Evaporation.	Evaporation. Residue then charred, extracted with water, and the filtered extract titrated.	Evaporation with Sodium Carbonate. The residue then charred, extracted with water, and the filtered extract neutralised with nitric acid and then titrated.
No. 1	Sewage	3·63	—	3·50	—	3·52
2	1st Field effluent	—	5·17	—	—	5·14
7	Sewage	—	10·00 / 10·08	10·06	—	—
—	Diluted sewage	—	4·14	3·80	—	—
9	2nd Field effluent	—	10·00 / 10·15	10·20	—	—
8	1st Field effluent	—	9·40	9·36	—	—
—	Sewage	—	—	—	6·80	7·64
—	Sewage	—	—	—	8·36	8·94

* *Cf.* Dittmar, "Quantitative Chemical Analysis," pp. 219–220.

Some later comparative estimations, done in February, 1904, have given the following results :—

Number of Sample.	Nature of Sample.	Evaporation to 5 c.c.	Evaporation to dryness alone.	Evaporation to dryness with 10 c.c. of a solution of bicarbonate of lime, etc., and subsequent titration.
No. 3395	Septic tank liquor	10·34	10·24	10·22
3396	Continuous filter effluent	10·04	10·20	10·14
659	Septic tank liquor drawn on January 18th, and with the solids now aggregated together	14·80	14·60	14·84
3400	Septic tank liquor	3·68	3·72	3·78

It may therefore, we think, be taken that, within the limits of accuracy necessary here—the organic matter in solution in a filtered sewage, tank liquor or effluent, which has been concentrated by evaporation, does not sensibly reduce silver nitrate during the short time required for the titration of the chloride present.

Note.—A solution of bicarbonate of lime is a very useful form of base for preventing loss of chloride during the evaporation of such solutions as the above, and the subsequent charring of the residue. The excess of lime helps to keep the residue porous, and as it is finally left in the state of normal carbonate it is readily filtered from the aqueous solution ; further, this solution can be titrated direct with silver nitrate, *i.e.*, it does not require the addition of any nitric acid.

Gravimetric Estimation of Total, Suspended and Soluble Solids.

(*a*) *Total Solids.*—50 to 100 c.c. of a sewage or tank liquor and 100 to 250 c.c. or even 500 c.c. of an effluent are evaporated to dryness on the water-bath, in a small porcelain basin whose weight should not exceed 20 grms. (platinum is, of course, preferable), and the residue is dried in the air-bath at 110° C. until its weight becomes constant. In the case of sewages and tank liquors this is often a very tedious process, and indeed the weight sometimes goes on decreasing almost indefinitely, no doubt from the slow volatilization of certain organic compounds present. On the average a residue ought to be dry, or nearly dry, in four days. By igniting the basin with the dried residue—igniting *very* gently in the first instance—also tedious in the case of sewages and tank liquors, and again weighing, an approximation is obtained between the *Volatile* and *Non-volatile* matter present.

Note.—If the sample should be acid from the presence of fixed acid, a slight known excess of alkaline carbonate should be added before evaporation.

(*b*) *Soluble Solids.*—The same operation as has just been described is gone through with a similar quantity of the sample, filtered through paper.

(*c*) *Suspended Solids, by difference.*—The difference in weight between (*a*) and (*b*) represents the Solids in Suspension.

The above process does not, of course, give all the solids, for ammonium

carbonate and any other solids volatile at 100° C. are lost in the evaporation and drying. There may also be a loss of chlorine if magnesium chloride is present. Further, the ignition of the two residues, especially in the case of effluents containing nitrate, must leave the bases partly in the state of carbonate and partly as oxide. The above ignition, therefore, can only be taken as an indication whether there is anything abnormal in an effluent; in a sewage or tank liquor it must give a fair approximation to the amount of organic matter present.

A fairly correct result, in the case of effluents, has been obtained by other workers (*e.g.*, in the Massachussetts experiments) by the addition to the liquid of a known quantity of sodium carbonate, *before* evaporation.

In the Land investigation * very few estimations of solids were made, except in the case of the average hourly samples of sewage, and in these the suspended matter was determined by difference, as above. In the case of effluents or other liquids containing only small quantities of suspended solids, this method *by difference* is not to be recommended. It means the estimation of a very small weight by the difference of two relatively large weights; and, as the residues are usually very hygroscopic, this tends to increase the error.

Suspended Solids:—Direct Determination of, by the Gooch Crucible.

For a considerable time past we have made all determinations of suspended solids by filtration of 50 to 500 c.c. (according to the sample) through asbestos in a Gooch crucible. This filtration is, of course, not always perfect, and the filtrate from a sewage or tank liquor or an imperfectly purified effluent always throws down a further small quantity of solid upon standing, as the following examples show:—

			Suspended Solids.	
No. 3091A.	Settled Sewage	1st Filtrate, Jan. 20th, 1903	3·84	3·00 volatile. 0·84 non-volatile.
		2nd Filtrate, Jan. 27th, 1903	0·92	0·82 volatile. 0·10 non-volatile.

			Suspended Solids.	
No. 3093B.	Primary Effluent	1st Filtrate, Jan. 30th, 1903	5·7	4·0 volatile. 1·7 non-volatile.

The filtrate did not look good, but after standing for seven days it had deposited only a very small amount of very light solid.

			Suspended Solids.	
No. 3255.	Secondary Effluent	—	0·85	0·82 volatile. 0·03 non-volatile.

This estimation was made by the Gooch method after the effluent had stood in a partly filled bottle for three weeks. At the time the analysis proper was made, the centrifuge showed only a trace of solid.

			Suspended Solids.	
No. 3144.	Storm Overflow Water	1st Filtrate, May 6th, 1903	394·2	45·3 volatile. 348·9 non-volatile.
		2nd Filtrate, May 13th, 1903	13·9	2·1 volatile. 11·8 non-volatile.

But, with this proviso, we have satisfied ourselves that the results obtained with the Gooch crucible are thoroughly consistent and reliable. It has been stated that the asbestos of a "Gooch" does not always keep a constant weight if it is washed with water, or with salt solutions and water, and then re-ignited and re-weighed; and some preliminary experiments made by us appeared to bear this out. But subsequent investigations with regard to this, in which the ignited and weighed "Gooch" was washed with water,

* Part II., Chemical Report, by Dr. G. McGowan.

re-ignited and re-weighed, have shown no such variations in weight, and we have, therefore, no hesitation in recommending the method for the determination of the suspended solids of a sewage, tank liquor or effluent. The ignition of those solids, too, gives a reliable result as regards volatile and non-volatile matter.

The asbestos to be used for the filtration should be in long silky fibres. A considerable quantity of this is first washed with water, to remove palpable dust, and then digested (not boiled) with strong crude hydrochloric acid for several hours. After this it is again roughly washed, and digested with successive small quantities of pure acid until the latter is no longer coloured by iron. Finally, it is thrown on to a funnel and washed with distilled water over the pump until the filtrate shows no trace of hydrochloric acid with silver nitrate solution, after which it is stored in a stoppered bottle under water.

A layer of the above asbestos, about 3 m.m. ($\frac{1}{8}$ in.) deep, is spread as evenly as possible over the bottom of a Gooch crucible, 44 m.m. ($1\frac{3}{4}$ in.) high by 38 m.m. ($1\frac{1}{2}$ in.) in diameter at the top, and the crucible is ignited and weighed. The latter is then carefully fixed into the filter flask by means of a piece of stout wide rubber tubing, which makes an air-tight joint when the pump is in use. After moistening the asbestos with water, as much as possible of the sewage or effluent is passed through it *without* the aid of the pump, the first portions of filtrate being, if necessary, refiltered. By proceeding in this way the pores of the filter clog less rapidly than if the pump is used from the beginning. At the end of the filtration the asbestos must, of course, be well washed with successive small quantities of water, to free it from all soluble matter. The crucible is then dried at 110° C. until its weight is constant; after that it is ignited at a moderate temperature, and again weighed for non-volatile matter.

Suspended Solids: Direct estimation by filtering through :—

(*a*) *Toughened Filtered Paper, with the aid of a pump.*

Before finally adopting the Gooch crucible we made some filtrations through toughened filter paper, the washed solids being subsequently transferred to a weighed basin by a jet of water from the wash bottle. The water was then evaporated off, and the basin dried at 110° C. and weighed; then ignited and weighed again. This plan was, however, found to be not altogether satisfactory, from the difficulty of getting the solids completely off the filter. But it is a fairly good, though slow, alternative method.

(*b*) *A tared filter of ordinary paper dried at* 100° *or* 110° *C.*

This has also been tried. Here, of course, the pump cannot be used. If quick filtering paper is employed, the filtrate is unsatisfactory, and if slow filtering paper, the filtration may last almost indefinitely. Besides, the drying and weighing of filter papers consumes a good deal of time. We do not, therefore, recommend this plan.

Suspended Solids :—Determination by Settlement, Centrifugalising, and Weighing combined.

With the view of saving time, our colleague, Mr. Colin C. Frye, made use of the following method in the year 1901 for determining the suspended solids in the Accrington filter effluent. A litre of effluent was allowed to stand for three days in a tall narrow beaker* and then the liquid was siphoned off. The residual mud, along with as little water as possible, was

* Should the weather be at all warm, the beaker would have to be kept cool, *e.g.*, in an ice-box, in order to prevent the solids from putrefying and being brought to the surface by gas bubbles.

transferred to a large centrifuge tube (capacity 25 c.c.),* the centrifuge rotated, and the supernatant liquid then removed. The solids were once more rotated with a fresh addition of distilled water, after thorough mixing with the latter, in order to get them practically free from salts, washed with as little water as possible into a small weighed crucible, dried (finally at 110° C), and weighed.

The following comparative results were obtained :—

—	Parts per 100,000.		
	Weighed Filter Method.	Gooch Method.	Decantation Method.
Effluent of February 15th, 1901 - -	4·60	—	4·50
„ March 19th, 1901 - - -	—	9·84	9·80
„ April 11th, 1901 - - -	—	7·24	7·52
„ April 31st, 1901 - - -	—	30·50	30·70
„ July 23rd, 1901 - - -	—	11·60	12·00
„ September 17th, 1901 - -	—	12·16	12·16

This decantation method is thus good where an effluent with well coagulated solids is concerned. A few results obtained with septic tank liquors were much less satisfactory; hence the method would have to be tested fully with sewages and tank liquors before anything definite could be said with respect to these.

Volumetric Estimation of Solids by the Centrifuge.

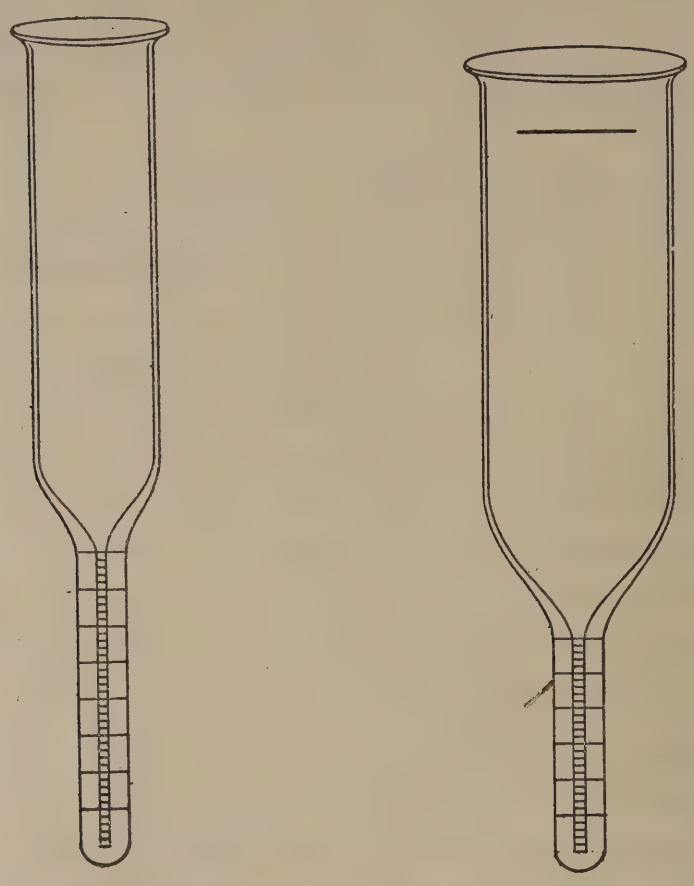
The idea of arriving approximately at the quantity of solids present in a sewage or effluent by means of the centrifuge is due to Professor Boyce. We have now made use of this apparatus for years and, as will be seen by referring to the chemical section of the Land Report,† the relation between the volume occupied by the suspended solids or, rather, the mud in a settled sewage, as measured by the centrifuge, and the dry weight of those solids was found to be fairly constant for the same place. Most of the samples tested consisted of settled sewage; with crude sewage there would obviously be much greater divergences. We have since then accumulated a large number of data with respect to the suspended solids of numerous other sewages, tank liquors, and effluents from artificial processes, but these have still to be collated. A determination by the centrifuge is a matter of a few minutes only; so, assuming a sufficient number of comparative gravimetric estimations to have been made in the first instance for any one place, and assuming these to be fairly concordant, the value of the centrifuge for giving an approximate idea of the quantity of suspended solids in a sample is self-evident.

The centrifuge used is completely covered by a round guard of strong sheet iron, 30·5 c.m. ($12\frac{1}{4}$ in.) in diameter and 11·5 c.m. ($4\frac{1}{2}$ in.) deep, which is screwed on either side to a firm projecting bar of steel; if such a guard be omitted, fatal accidents may result. The speed is about 2,000 revolutions for 90 turns of the handle per minute. We have found by experiment that three minutes at this rate is a sufficient length of time to allow the solids to aggregate in the narrow part of the tube, either to their full extent, or, at all events, nearly to that.

* A larger tube would, of course, be preferable, supposing the centrifuge strong enough to carry it.

† Part II., Chemical Report by Dr. G. McGowan

Figures 4 and 5 give the actual size of the tubes employed. The



FIGURES 4 AND 5.

ACTUAL SIZE.

smaller of these, holding 10 c.c., is of sufficient size for a determination of the mud in a sewage or tank liquor, while the larger one of 25 c.c. is desirable for effluents, unless these contain much suspended solid. When using the larger tubes we do not find it safe with our present centrifuge to go beyond about 1,700 revolutions per minute. The lower portion of each tube is a wide capillary, and this portion is, of course, carefully calibrated with mercury in the first instance. Each division of the smaller tube has a volume approximately of ·0013 c.c., and each division of the larger one a volume of ·0022 c.c. The exact quantity of 10 c.c. or 25 c.c. of the sample is filled into the tube from a pipette. For cleaning out the tubes the bristle of a broom is useful; it is important to avoid scratching the glass.

NOTE.—Such narrow tubes are naturally unsuitable for sewages containing very coarse solids.

ESTIMATION OF "CELLULOSE" IN SEWAGES, ETC.

An exact estimation of cellulose is a long and tedious process, the details of which are to be found in Messrs. Cross and Bevan's well-known book on cellulose. But the following simple plan which we adopted may be taken as giving a rough approximation, subject to what is said on p. 51; or, at all events, it gives comparative results by the same process.

250 c.c. of a sewage or 500 c.c. of a tank liquor are boiled for 30 minutes in a porcelain basin (*in a draught cupboard*) with so much potash or soda solution that the whole liquid contains 0·67 per cent. by weight of KOH or 0·5 per cent. NaOH; during the boiling the liquid is kept up to its original volume by small additions of hot distilled water from time to time. The

mixture is then passed through a filter of German paper (which does not shed its fibres readily), washed nearly free from alkali, re-transferred to the basin by the wash-bottle, and again boiled for 30 minutes in a solution of equal volume (250 c.c.) containing 0·5 per cent. by weight of sulphuric acid (H_2SO_4). After again filtering (through a small filter) and washing free from acid with water,* the filter with its contents is next washed several times (or extracted) with alcohol, and finally extracted for half an hour with ether in a suitable extraction apparatus. The ethereal extract is usually yellow in colour, and leaves a fatty residue on evaporation, showing that saponification by the dilute alkali has been incomplete. The cellulose and grit are then carefully washed from the filter into a small weighed basin, the water evaporated on a water bath, and the basin dried at 110°C. until its weight is constant. It is then ignited and weighed again. The first weighing gives the "cellulose" and grit together, and the second the grit alone.

The following duplicate estimations of "cellulose" in a number of sewages, (*a*) by boiling with dilute alkali and acid only, and (*b*) by extracting also with alcohol and ether, show that much fatty matter was still left in the former case :—

Number of Sample.	Farm.	Nature of Sewage.	"Cellulose":—parts per 100,000.	
			Extracted.	Not extracted.
No. 455	South Norwood	Screened and settled	2·88	5·88
,, 460	Aldershot Camp	,,	3·88	10·68
,, 464	,,	,,	4·00	12·68
,, 466	Nottingham	Screened and crude	15·08	24·96
,, 467	,,	,,	6·24	15·32
,, 468	,,	,,	5·32	14·96
,, 469	Leicester	Screened and settled	6·56	12·12
,, 471	,,	,,	5·80	11·80
,, 472	Rugby	,,	7·88	10·96
,, 474	,,	,,	5·88	12·96
,, 475	Cambridge	,,	5·08	7·16
,, 476	,,	,,	4·32	7·60
,, 477	,,	,,	3·84	5·84

The Action of an Acid Solution of Potassium Permanganate upon the Celluloses of Sewage.

A few experiments may be cited here which we have made with the object of determining the effect of the 4 hours "oxygen absorbed" test at 80° F. upon the cellulose compounds found in sewage.

(1) *Pure cellulose*, as is known, is not affected by an *acid* solution of permanganate (Cross and Bevan, *loc. cit.*) A gramme or so of good Swedish filter paper was cut up into small pieces about 1 m.m. square, and boiled for an

* It is most important that the precipitate should not be allowed to become dry on the filter at any time.

hour with a 1·5 per cent. potash solution; after being washed free from alkali it was boiled for half an hour with a dilute solution of sulphuric acid (0·5 per cent. by weight), again washed, dried, and finally extracted successively with alcohol and with ether for an hour in each case. The product, which was now pretty finely divided, was then dried for four days at 100° C. until its weight became constant.

The 4 hours "oxygen absorbed" test at 26·7° C. (80° F.) was then made upon 0·0567 grm. of the above, together with 200 c.c. of the ordinary permanganate solution (3·9 grm. per litre), 200 c.c. water and 200 c.c. of 10 per cent. sulphuric acid. At the end of that time the mixture was filtered through Swedish filter paper, some peroxide of manganese which had precipitated on to the filter was washed out with an acid solution of potassium iodide, and then the whole was washed thoroughly with water. By the aid of a wash-bottle the residue was then transferred to a weighed basin and dried at 100° C. until the weight was constant. The cellulose found amounted to 0·0585 grm., as against 0·0567 taken, *i.e.*, *the whole amount was recovered.*

That no permanganate is used up when pure cellulose is submitted to the conditions of the "oxygen absorbed" test at 80° F. is further shown by the following experiment:—0·0387 grm. of the prepared cellulose* was disintegrated by grinding to a pulp with water, and the mixture was then diluted to 200 c.c. with distilled water. Two portions of this, (*a*) and (*b*), each of 10 c.c., were then mixed with 10 c.c. permanganate solution and 10 c.c. sulphuric acid (10 per cent.), and warmed for four hours as usual at 80° F. They were then titrated, alongside of a "blank" (*c*):—

(*a*) required 34·75 c.c. thiosulphate solution;
(*b*) ,, 34·79 ,, ,, ,, ;
(*c*) ,, 34·75 ,, ,, ,, .

This proves conclusively that any pure cellulose in a sewage or effluent takes up no oxygen from permanganate in the "oxygen absorbed" test.

The case is however different with paper pulps which do not consist of pure cellulose, thus:—

2.—(*a*) *A cotton rag paper* of a light brownish tint was pulped and extracted with ether, and 0·0592 grm. of the dried residue was subjected to the four hours "oxygen absorbed" test at 80° F. The result showed an oxygen absorption of 0·0056 grm., or 100 parts by weight of the extracted pulp absorbed 9·46 parts of oxygen.

(*b*) 0·0576 grm. of the same pulp, *not* previously extracted with ether, took up 0·0061 grm. oxygen, or 100 parts absorbed 10·59 parts oxygen.

(3) *Wood pulp paper*,† of a pale yellow colour:—

(a.) 0·0479 grm. of the dried pulp, previously extracted with alcohol and ether, took up 0·0072 grm. oxygen from the acid permanganate, *i.e.*, 100 parts absorbed 15·03 parts oxygen.

(b) 0·0588 grm. dried pulp, not extracted with alcohol and ether, took up 0·0087 grm. oxygen, or 100 parts absorbed 14·79 parts oxygen.

NOTE.—In the last two cases, but more especially in the second experiment (b), the permanganate was nearly exhausted at the end of the four hours' warming, and so the figures obtained are probably somewhat below the true values.

---

* The proportion of cellulose to liquid in this and the following experiments was approximately what one finds in an average sewage.

† This paper gave the ligno-cellulose reaction with aniline sulphate.

Experiments were also made with a *crude sewage* drawn on March 4th, 1902, in order to determine the difference, if any, in the amounts of "cellulose" found :—

(1) In the original sewage ;

(2) In the sewage after subjection to the 4 hours "oxygen absorbed" test at 80° F. [for this treatment with acid permanaganate 200 c.c. sewage, 200 c.c. permanganate and 200 c.c. sulphuric acid (10 per cent.) were taken.] Two separate quantities *of the same sewage* were treated in each series of experiments, the product from one portion of each being extracted with ether. The following figures were obtained :—

Parts per 100,000 by Weight.

	(*A*) Without Permanganate Treatment.	(*B*) After 4 hours' Permanganate at 26·7° C. (80° F.).
Series I., March 5th, 1902.		
(*a*) Cellulose and Fatty Matter -	13·44	3·07
(*b*) Cellulose (after extraction with Ether)	5·76	3·20
Grit from (*a*) - - - -	4·04	2·30
Grit from (*b*) - - - -	4·00	2·50
Series II., March 7th, 1902.		
(*a*) Cellulose and Fatty Matter -	14·56	2·90
(*b*) Cellulose (after Ether) -	6·00	2·40
Grit from (*a*) - - - -	4·16	2 90
Grit from (*b*) - - - -	3·92	2·85

From the foregoing results it is seen :—

(1) That the four hours' treatment with acid permanganate at 80° F. removes practically all the fatty matter from sewage (at least from the above sample). This treatment (with a 3·3 per cent. sulphuric acid solution) has also a very solvent action on the grit present, as compared with the action of the very dilute acid used in a cellulose determination at 100° C. ;

(2) That the method given for "cellulose" determination on p. 48 is, as has been already said, only an approximate one, leaving as it does, instead of pure cellulose, a mixture which yields up about half its weight to the permanganate in the four hours test. The method would therefore be improved by the inclusion of this permanganate treatment. The subject requires further investigation, but these results at least help to show what the permanganate of the four hours "oxygen absorbed" test does not attack.

Estimation of the Dissolved Gases in Waters, Effluents, etc.

In the earlier part of the land investigation, the extraction of the gases present in solution in effluents, etc., and the subsequent analysis of these gases were done in the apparatus devised by Dr. W. E. Adeney, and fully described by him in the *Transactions of the Royal Dublin Society*, Vol. V. (Series II.), page 39 *et seq.* In this apparatus the gases from a given volume of effluent (usually about 200 c.c.) are boiled out *in vacuo*, and measured at known temperature and pressure over moist mercury in a carefully calibrated burette. As a matter of personal preference, however, we have substituted for the "laboratory vessel" a bent capillary which delivers the gases into a loose uncalibrated tube, in which they can be kept for any length of time. And for an absorption apparatus we employ a tube about 12 to 13 c.m. long by 19 m.m. internal diameter, drawn out as shown in Figure 6. By

Figure 6.
Not to Scale.

having the tube of this shape one is able, with practice, when making an analysis, to return the whole of the unabsorbed gas to the burette quite free from any traces of absorbent (potash, etc.); or, if a minute bubble of gas is left behind, this measures only 0·01 to 0·02 c.c., and can be allowed for.

The volume of gas obtained from a land effluent depends mainly upon whether it comes from a surface irrigation or a filtration farm; in the latter case the amount of "free" carbon dioxide may be very great. The gases from the Nottingham and Aldershot Camp farm effluents may be taken as representing filtration farms, and those from the South Norwood and Leicester effluents surface irrigation farms. In practically all cases, however, 200* c.c. of effluent give a suitable quantity of gas for analysis, whether the liquid be boiled out without or with the previous addition of a little dilute sulphuric acid, according as nitrite is present or absent. This liquid must of course be drawn into the Adeney apparatus from the lower portion of the containing bottle, immediately after the latter has been opened.

It is unnecessary, when examining a water or an effluent in the course of an ordinary analysis, to look for any other gases than carbon dioxide, oxygen and nitrogen. For absorbing the carbon dioxide we use a few drops (about 0·25 to 0·3 c.c.) of rather strong potash (three times normal or a little stronger), and for absorbing the oxygen about the same volume of aqueous pyrogallic acid (roughly 1 in 10, or stronger). These are introduced into the absorbing tube by means of a small bent pipette, and it helps to keep one's mercury clean if, after drawing up an absorbent into the pipette, the latter is then dipped into a small glass of mercury, then into water and dried with paper, the pipette being thus sealed with mercury.

The use of this apparatus for following out the fermentative changes in polluted waters has been fully described by Dr. Adeney in the paper referred to, and other later ones.

The apparatus is also, of course, equally well suited for the examination of gases drawn from filter beds or evolved from septic tanks, or, indeed, for the analysis of any mixture of the ordinary gases, and we have used it largely for these purposes. When carbon monoxide has to be tested for, we use as absorbent a few drops of a solution of cuprous chloride in hydrochloric acid, afterwards made alkaline with ammonia in the absorbing tube; and after the absorption of the carbon monoxide we wash the residual gas with a very little water before proceeding to examine it further for methane

* Actually 200 c.c. plus the small volume representing the capacity of the capillary and inlet tube to the burette; this was in our case 2·6 c.c.

and hydrogen. Should one or both of the latter gases be present in the residual nitrogen, a suitable quantity of this residue is exploded with a measured volume of pure oxygen* in an ordinary explosion tube. All the readings are, of course, done in the Adeney burette.

The order in which the gases are estimated in such a mixture as has just been described is :—

1. Carbon dioxide.
2. Oxygen.
3. Carbon monoxide.
4. Hydrogen and Methane.
5. Nitrogen.

In conclusion :—After a long experience of this apparatus we can only record our testimony as to its great value, both with respect to convenience of working and to the accuracy of the results obtained.

Quick Approximate Determination of Dissolved Oxygen in Waters and Effluents.

When an approximate estimation of the *Dissolved Oxygen only* in a water or an effluent is required, the method worked out by Sir William Ramsay and Miss Ida Homfrey is often very convenient (*Journal of the Society of Chemical Industry, November*, 1901). As is well known, it depends upon the oxidation in ammoniacal solution of colourless cuprous to blue cupric salt, the depth of the blue being then compared with that of standard tubes representing 1, 2,——8 c.c. of dissolved oxygen per litre.

The apparatus and procedure are so fully described in the paper already cited that only a few further notes need be added here.

For the preparation of *Cuprous chloride* we have always followed Wöhler's method (*Annalen der Chemie*, Vol. 130, p. 373), *viz.*, a nearly-saturated solution is made of equivalent quantities of sodium chloride and cupric sulphate (*i.e.* $2NaCl + CuSO_4, 5Aq$), allowed to stand overnight, and filtered clear next day. Sulphurous acid gas, well washed, is then passed through this solution to final saturation, the end of the gas tube which dips into the liquid being enlarged to a sort of small cup or funnel, so as to obviate risk of stoppage as the cuprous chloride crystallizes out. The resulting magma having been allowed to stand in its *stoppered* vessel overnight, to get some further crystallization, it is then *rapidly* passed through a funnel containing a platinum cone only, by the aid of the filter pump, pressed with a glass spatula, washed a few times successively with aqueous sulphurous acid, alcohol and ether, and dried preferably *in vacuo* in the dark over sulphuric acid. No time must be lost over the filtration and washing. In this way one easily obtains a good stock of pure dry cuprous chloride. It should be kept in a stoppered tube placed inside a larger one containing some fragments of chloride of calcium, the whole being wrapped round with black cloth ; from this a little of the salt is transferred, as required, to the tube in daily use (which must also be coated with black paper and kept over calcium chloride). Only a minute quantity of this cuprous salt is required for an oxygen estimation.

Preparation of Standard Tubes. These can be conveniently prepared from time to time by saturating distilled water with air at a known temperature and comparing the blue which this gives with cuprous chloride, etc., with that of a dilute solution of cupric sulphate containing excess of ammonia. The volume of oxygen necessary to saturate distilled water at a given temperature being known, its colour equivalent in

* This is most conveniently prepared by heating a little permanganate of potash in a tube of hard glass, and passing the escaping gas over soda lime before collecting it.

ammoniacal cupric sulphate can be easily made, and proportionate amounts of the latter can be taken to make up the standards with pure distilled water and ammonia. These standards should always contain a large excess of ammonia, and it is needless to say that the tubes ought to be scrupulously cleansed beforehand, and that the blowpipe flame should never be allowed to impinge on the inside. They are best filled through a long, thin funnel-tube, after which they are sealed by a small blowpipe flame (*See* Figure 7).

FIGURE 7.
NOT TO SCALE.

It should be borne in mind that the colour in the standard tubes gradually fades, hence these should be renewed at intervals, say, every six months or so. The extent of this loss of colour by the ordinary sealed standard tubes is shown by the following readings ; when not actually in use these tubes had been kept in the oxygen box, *i.e.* they had been in the dark nearly all the time.

VALUES OF OLD STANDARD TUBES AS READ AGAINST NEW ONES.

Original value.	A. Tubes made probably towards the end of July, 1900. Re-standardized Nov. 27th, 1900.	B. Tubes made probably towards the end of July, 1900. Re-standardized Nov. 27th, 1900.	C. Tubes made Nov. 27th, 1900. Re-standardized Aug. 14th, 1902.	D. Tubes made Aug. 14th, 1902. Re-standardized Aug. 10th, 1903.	E. Tubes made Aug. 10th, 1903. Re standardized Aug. 21st, 1904.
1 c.c.	0·6	0·0	Trace.	Rather less than 1·0	0·85
2 c.c.	1·6	1·75	1·4	1·6	2·0
3 c.c.	2·5	2·3	1·75	2·8	3·0
4 c.c.	3·3	3·1	3·1	4·1	4·0
5 c.c.	4·3	3·5	1·5	4·85	5·0
6 c.c.	5·6	5·75	2·0	5·9	5·85
7 c.c.	—	—	3·4	6·8	6·5
8 c.c	—	—	1·9	7·0	8 0

If this method is carried out with ordinary care, there is no difficulty in getting a blank—or practically a blank—result with boiled-out water or effluent. Again, in the case of drinking waters and colourless or nearly colourless effluents, the oxygen figures obtained are substantially correct. Further, it is very rare to find in any effluent, whether from land or artificial processes, sufficient nitrite to interfere materially with the estimation. Considering, therefore, the ease and rapidity with which an approximate determination of dissolved oxygen can be made in this way, the method is—within its limits—of great value, more especially when the aeration of the water of a stream has to be determined on the spot. With the ordinary blue standard tubes, however, the process is not applicable to effluents which are at all deeply coloured, the addition of the ammoniacal cuprous chloride giving with these a green instead of a blue colour. The authors of the method got over this difficulty in the laboratory by adding a trace of an alkaline solution of para-nitrophenol (after the other reagents) to the open-tube standard, in order to give it a colour similar to that produced by the (yellow or brown) effluent. We have not ourselves tried whether *permanent* green standard tubes could be thus made, but it would be desirable to do this.

Determination of the Dissolved Oxygen in Waters and Effluents by Winkler's Method as modified by Rideal and Stewart.—[*"Analyst," Vol.* 26, *p.* 141 (1901)].

We have latterly made most of our determinations of dissolved oxygen by the above method, and have found it very satisfactory, and also fairly quick. The principle on which it depends is the oxidation in an alkaline liquid of manganous oxide to a higher oxide of manganese, the subsequent liberation of iodine from potassic iodide by this in the now acidified solution, and the titration of the liberated iodine by thiosulphate. Full details of the process are given in the paper just cited, but the main points may be repeated shortly here.

Solutions required:—

(1) Concentrated sulphuric acid.

(2) Deci-normal permanganate of potash.

(3) A 2 per cent. solution of potassium oxalate.

(4) A 33 per cent. solution of manganous chloride.

(5) A mixed solution containing 50 per cent. caustic soda and 10 per cent. potassium iodide.

(6) Concentrated hydrochloric acid free from chlorine.

(7) $\frac{N}{20}$ Sodium thiosulphate.

Process.—A stoppered bottle of about 300 to 350 c.c. capacity is completely filled with the sample of water or effluent, avoiding any appreciable aeration in doing this, and 1 c.c. sulphuric acid together with sufficient of the permanganate solution are added, to leave a slight excess of permanganate after the whole has been mixed and has stood for 10 minutes (the object of this is to oxidize any nitrite present to nitrate). The proper amount of permanganate is best determined by a preliminary trial on, say, 25 or 50 c.c. of the sample; this having been done, about 0·1 c.c. in excess of the calculated quantity of permanganate is added to the bottle-full taken for analysis. After 10 minutes any excess of permanganate is destroyed by the addition of 0·5 to 1·0 c.c. of the oxalate solution, the bottle being quickly opened and re-stoppered. When the liquid has again become decolorized as regards permanganate, 1·0 c.c. of the manganous chloride is run in at the bottom of the bottle from a pipette, and immediately afterwards 3·0 c.c. of the mixed soda and iodide solution in the same manner.

The bottle is then closed, rotated to mix its contents, and the precipitated oxides of manganese are allowed to settle. After this 5·0 c c. of hydrochloric acid are run in, also at the bottom of the bottle, and the bottle kept in the shade for five to 10 minutes, with frequent shaking. It now only remains to transfer the liquid to a porcelain basin and titrate the liberated iodine with thiosulphate. The oxygen-equivalent of the latter being known, the amount of dissolved oxygen present in the sample is readily calculated. A slight correction can, if wanted, be introduced for the volume of the liquid displaced by the reagents and for the dissolved oxygen contained in these latter.

As already stated, we have found this method very satisfactory, although time has not yet allowed of more than one or two comparative determinations by ourselves between this process on the one hand and the boiling-out and copper chloride methods on the other. Once the necessary solutions have been made, the time required for an oxygen determination by the manganese method is about an hour, other work being sandwiched in, while several such estimations of oxygen can be done alongside of one another with very little additional expenditure of time.

Analysis of Soils.

The methods adopted for the mechanical analysis of soils and subsoils, together with the determination of the lime in these, are fully detailed in the Chemical section of the *Report on Land Treatment of Sewage** pp. 275–301.

Analysis of Sludges from Filter Beds and Tanks.

A number of these have also been examined more or less fully. Any details worthy of mention will be given under the analysis of the individual sample.

Heavy Metals in Sludges and in Effluents.

Beyond making an estimation of the arsenic in various sludges, we have not yet done any work, to speak of, on this subject. The method adopted for the determination of arsenic was the basic method of Newlands and Ling, followed by precipitation as sulphide and subsequent marshing. For details, see the *Report of the Royal Commission on Arsenical Poisoning* (1903), Vol. II.†

---

* Part II. Chemical Report, by Dr. G. McGowan.
† Appendix 23, p. 227. McGowan and Floris on "Tests for Arsenic in Fuel."

APPENDIX 1.

Changes undergone by Sewage when kept in a full bottle (not in the dark).

On Monday, 9th June, 1902, at 11 a.m., three Winchesters of Ealing Sewage were drawn. At 5 p.m. in the laboratory their contents were poured into a large pail, and any large pieces of paper and other coarse solids were rejected. The pail was then kept constantly stirred, and four half Winchesters were filled from it by pouring into each a beakerful in turn, *i.e.*, every bottle received one beaker before the second beakerful was poured into any. So far as could be judged, the samples were very even. The bottles were filled completely and kept at laboratory temperature.

	No. 1.	No. 2.	No. 3.	No. 4.
nalysed - -	10th June, 1902	11th June, 1902.	12th June, 1902.	16th June, 1902.
Parts per 100,000 *by weight.*				
mmoniacal nitrogen - - -	9·98	10·21 } Two drops of Na_2CO_3 Aq. added.†	10·68 } Two drops of Na_2CO_3 Aq. added.	11·78 } Six drops of Na_2CO_3 Aq. added.
lbuminoid nitrogen - - -	1·82	1·79	1·54	0·72
itrous nitrogen -	0·0	——	——	——
itric nitrogen -	* Not tested for.	——	——	——
otal nitrogen by Kjeldahl method	13·56	13·48	13·49	13·57
ank - - -	(0·33 in 10·19)	(0·33 in 10·13)	(0·33 in 10·14)	(0·33 in 10·20)
X " nitrogen -	1·76	1·48	1·27	1·07
otal Organic nitrogen - -	3·68	3·27	2·81	1·79
Oxygen absorbed" from permanganate at 26·7° C. (80° F.) *at once* -	3·00	3·39	3·93	5·10
Oxygen absorbed" from permanganate at 26·7° C. (80° F.) *after* 4 *hours* - -	16·87	15·77	15·23	14·53
lorine - -	10·60	10·60	10·54	(*a*) 10·66 (*b*)‡ 10·50 (*c*) 10·30
otal solids (gravimetrically)	119·7 { 56·4 Volatile 63·3 Non-Vol.	115·7 { 53·6 Volatile. 62·1 Non-Vol.	114·1 { 53·4 Volatile. 60·7 Non-Vol.	112·3 { 55·8 Volatile. 56·5 Non-Vol.
lids in suspension	42·1 { 28·9 Vol. 13·2 Non-Vol.	40·3 { 30·2 Vol. 10·1 Non-Vol.	40·2 { 34·1 Vol. 6·1 Non-Vol.	36·9 { 29·4 Vol. 7·5 Non-Vol.
lids in solution -	77·6 { 27·5 Vol. 50·1 Non-Vol.	75·4 { 23·4 Vol. 52·0 Non-Vol.	73·9 { 19·3 Vol. 54·6 Non-Vol.	75·4 { 26·4 Vol. 49·0 Non-Vol.
Parts per 100,000 *by Volume.*				
ids by centrifuge	289	244	257	199
marks - -	Turbid and brown. Not a very large amount of brown sediment. Sewage smell. Alkaline.	The same in character as Sample No. 1.	Much the same as Nos. 1 and 2.	Rather more turbid than the preceding samples. There was now a smell of sulphuretted hydrogen along with that of sewage. Not appreciably blackened. Alkaline.

* Though in all probability no nitrate was present, it might have been well to have tested for it in the first instance.
† This solution was about half normal, *i.e.*, contained about 27 grms. Na_2CO_3 per litre.
‡ Estimations (*a*) and (*b*) were done by filtration and evaporation only; in the case of (*c*) a little sodium carbonate added before evaporating, and the residue was charred, etc.

During the week covered by the above estimations the temperature was very low for the season. On Tuesday, June 10th, the temperature of the sewage itself in the bottle was 16°—18° C. (61°—64° F.), and this would probably be about the average temperature throughout.

APPENDIX 1—*continued.*

The main conclusions to be drawn from this experiment are—

1. That sewage, in the absence of oxygen and nitrate, undergoes little change for the first two days at a moderate temperature, and for six days, at all events, there is no alteration in the total amount of nitrogen present.

2. The changes which it does undergo are in the following direction :—

   (A) The ammoniacal nitrogen increases slowly at the expense of the organic nitrogen, there being a steady diminution *both* in the " albuminoid " and in the " X " nitrogen.

   (B) There is a gradual increase in the amount of readily putrescible matter as measured by the " oxygen absorbed " from permanganate *at once.*

   (C) The suspended solids also show a slight diminution in quantity, but upon this point it is not safe to generalise without further data.

APPENDIX 2.

EXPERIMENTS showing the breaking-down effect of Water and Alkali upon Sewage :

(a) *Dilute Solution of Caustic Soda.*

Nov. 10th, 1898.—To 100 c.c. of sewage, 50 c.c. distilled water and 0·05 grm. of caustic soda were added, and the liquid was then distilled. Subsequently five other separate quantities of 50 c.c. water were added and the distillation was repeated after each addition, but ammonia still continued to be given off. *This proves that it is inadmissible to add to a sewage more than the slightest excess of alkali.*

(b) *Freshly-precipitated Silver Oxide.*

This was taken as being a mild "alkali."

1898. Nov. 14th -	70 c.c. Sewage, about 50 c.c. distilled water, and 0·2 grm. moist oxide of silver were taken :	Found :
,, ,, -	Distilled 50 c.c. - - - -	Too much ammonia to nesslerize.
,, 15th -	Added 50 c.c. water and distilled -	1st 25 c.c. - Nessler ; very dark brown. 2nd 25 c.c. - do.
,, ,, -	,, 50 ,, ,, -	1st 25 c.c. - do. 2nd 25 c.c. - - 0·000019 grm. NH_3.
,, ,, -	,, 50 ,, ,, -	1st 25 c.c. - - ·000015 (Pale yellow) 2nd 25 c.c. - - ·000002 (trace)
,, 16th -	,, 50 ,, ,, -	1st 25 c.c. - - ·000022 2nd 25 c.c. - - ·000009
,, ,, -	,, 50 ,, ,, -	1st 25 c.c. - - ·000009 2nd 25 c.c. - - ·000010 3rd 25 c.c. - - ·000009
,, 17th -	,, 50 ,, ,, -	1st 25 c.c. - - ·000015 2nd 25 c.c. - - ·000010

Moist oxide of silver thus breaks down sewage much less energetically than dilute caustic soda, but still its action is very marked.

(c) *Water alone.*

1898 Nov. 10th -	100 c.c. of sewage were mixed with 75 c.c. distilled water, and 75 c.c. of the mixture were distilled over. Then six further additions of water were made, as given below, 50 c.c. at a time :—		
		Distillate.	NH_3 found.
,, ,, -	100 c.c. sewage+75 c.c. water -	1st 75 c.c. - -	Too much to estimate
,, ,, -	50 c.c. water added - - -	2nd 50 c.c. - -	,,
,, ,, -	50 c.c. ,, - - -	3rd 50 { 25 c.c. - 25 c.c. -	,, 0·0001 grm. (*i.e.*, ·01 part per 100,000).
,, 11th -	50 c.c. ,, - - -	50 { 1st 25 c.c. 2nd 25 c.c.	·000019 ·000010
,, ,, -	50 c.c. ,, - - -	50 { 1st 25 c.c. 2nd 25 c.c.	·000007 none
,, 12th -	50 c.c. ,, - - -	50 { 1st 25 c.c. 2nd 25 c.c.	·000008 ·000003
,, ,, -	50 c.c. ,, - - -	50 { 1st 25 c.c. 2nd 25 c.c.	none none

These figures show that the hydrolytic action of water alone is not great in the time covered by an estimation.

A further experiment showed that if a sewage was distilled with water until it was ammonia-free, and if a given quantity of ammonium chloride in excess of water was added to the residual liquid and the latter redistilled, all the ammonia added was given off readily. The organic matter of the sewage does not therefore keep back ammonia.

APPENDIX 3.

Volatilisation of Ammonia from very Attenuated Solutions of Ammonium Salts, *when these are heated in glass vessels.*

It has long been known that, when a strong solution of ammonium chloride is warmed, a considerable quantity of ammonia escapes. But, so far as we are aware, no one has published the fact that all the ammonia escapes with the steam on distilling a very attenuated solution of an ammonium salt from a glass vessel, even if that solution contains a trace of acid. On discussing the point in the beginning of the year 1899 with the late Dr. A. P. Aitken, of Edinburgh, we found that he had already made the same observation, but had never published it. As Sir William Ramsay pointed out, this volatilisation was in direct contradiction to the electrolytic dissociation theory. It did not arise from the salt as a whole being carried over, for no hydrochloric acid (of the ammonium chloride) was found in the distillate. It was some time before it occurred to us that this volatility might be due to the action of the alkali in the glass; but subsequent similar experiments made with a platinum basin (in default of a platinum still) showed that this was the cause.

It will be noticed that the quantities of ammonia volatilised are quite appreciable when compared with the amounts in a sewage, an effluent, or a water.

The ammonia was added as chloride, sulphate, or nitrite, and the distillates were nesslerized in the usual way.

Distillation in a Glass Retort.

	NH_3. taken (Grms.):	NH_3 found (Grms.):	—
NH_3 (as NH_4Cl) - -	·00004 in 100 c.c. water	·0000395	Practically all came over in the first 50 c.c.
,, ,, - - -	·00020 in 100 ,,	·00019	,, ,, ,,
,, ,, - - -	·00097 in 140 ,,	·00094	This required two additions of 75 and 50 c.c. water, and re-distillation.
,, ,, - - -	·00664 in 175 ,,	·00398	This went on for a very long time, with many additions of water.
NH_3 [as $(NH_4)_2SO_4$] - -	·00005 in 150 ,,	·00005	Came over in the first 50 c.c.
,, (as $NH_4Cl+2H_2SO_4$)-	·00090 in 150 ,,	None.	—
,, (as $NH_4Cl+\frac{1}{4}H_2SO_4$)-	·00101 in 150 ,,	Only about 1 per cent. of the whole.	In first 50 c.c.
,, (as $NH_4Cl+\frac{1}{10}H_2SO_4$)	·00103 in 150 ,,	About 10 per cent. of the whole.	In first 50 c.c.
(as $NH_4Cl+\frac{1}{10}H_2SO_4$)	·00101 in 120 ,,	·00073	This required four additions of water of 100 c.c. each.

The reaction of this last solution to litmus paper was tried after the distillation. There was no perceptible change in the blue litmus after ten minutes.

Compare also the figures given in Appendix 4, pp. 62–63, for the distillation of dilute solutions of ammonium nitrite in glass and platinum.

Appendix 3—*continued.*

Distillation of dilute solutions of Ammonium Salts in a Platinum basin, the residual liquid being nesslerized.

	NH_3 taken (Grms.):	NH_3 found in the residue (Grms.):
NH_3 (as NH_4Cl) - -	·000050 in about 100 c.c water, which was evaporated down to 50 c.c.	·000050
,, (as NH_4Cl) - -	·000052 in 100 c.c. water, boiled down to 50 c.c.	·000049
,, (as NH_4NO_2) -	·000192 in 160 c c. water, boiled down to about 50 c.c. and made up to 100 c.c. with distilled water.	000166

For further details of this last experiment, *see* Appendix 4, p 63.

APPENDIX 4.

To SHOW the comparative stability of a dilute solution of Ammonium Nitrite kept in the dark.

The solution of Ammonium nitrite was made on May 26th, 1899, by grinding up silver nitrite with a dilute solution of ammonium chloride. It contained a slight excess of the latter.

May 26.—On this day it was standardised against potassium nitrite solution, which was afterwards standardised on June 5th against Permanganate and Thiosulphate :—

1 c.c contained - - 0·00001719 grm. Nitrous Nitrogen.

,, 29.—1 c.c. ,, - - 0·00001719 ,, ,, ,,

Standardised against a new solution of potassium nitrite :—

June 8.—1 c.c. contained - - 0·00001721 grm. Nitrous Nitrogen.

The *m*-phenylene-diamine method was used here.

The following estimations of the Ammoniacal Nitrogen of the Nitrite were also made :—

June 7.—1 c.c contained - 0·00001933 grm. Ammoniacal Nitrogen.

,, 8.—1 c.c. ,, - 0·00001923 ,, ,, ,,

The above figures show that a dilute solution of ammonium nitrite in distilled water is really very stable.

DISTILLATION of a dilute solution of Ammonium Nitrite from a glass retort, using (*a*) pure water, alone, and (*b*) water containing a trace of alkali. The solution also contained a little Ammonium Chloride.

May 29th, 1899.

(*a*) 500 c.c. water were boiled down to about 425 c.c., and then the ammonium nitrite was added. Three portions of 50 c.c. each were now distilled off and nesslerized separately :—

	Ammoniacal Nitrogen.
Taken (as NH_4NO_2) - - -	·000097 grm.
Found - - - - - -	·000097 ,,

(*b*) The same as (*a*), only in this case caustic alkali was added, equal approximately to ·00028 grm. of nitrogen, *i.e.*, equal to about three times the ammoniacal nitrogen of the added nitrite :—

	Ammoniacal Nitrogen.
Taken (as NH_4NO_2) - - -	·000097 grm.
Found - - - - - -	·000090 ,,

NOTE.—The assumption is made here that the dilute solution of nitrite used had not altered during the last two days ; it had been kept in the dark. (*Cf.* above.)

In the residual liquids, the nitrite (with probably a trace of nitrate) was estimated as ammonia by means of the copper-zinc couple.

		Nitrous Nitrogen.
Taken (as NH_4NO_2) -	·000086 grm.	·000086 grm.
Found - - -	·000072 ,,	·000079 ,

APPENDIX 4—*continued.*

DISTILLATION of dilute solutions of Ammonium Nitrite in Glass and Platinum. (A little Chloride of Ammonium was also present here.)

June 8th, 1899.—1. *Glass Retort.*

500 c.c. water + 5 c.c. of a dilute solution of NH_4NO_2 were taken and 150 c.c. were distilled off :—

Ammoniacal Nitrogen taken - - - -	·000096.
,, ,, found in distillate - -	·000101.

The residual liquid was then boiled down to 30 c.c., made up to 100 c.c. with distilled water, and the nitrite estimated in 20 c.c. of this by *m*-phenylene-diamine :—

Nitrous Nitrogen taken - - - - -	·000086.
,, ,, found - - - - -	·000075.

June 8th, 1899.—2. *Platinum Basin.*

150 c.c. water + 10 c.c. of the above NH_4NO_2 solution were boiled down to about 50 c.c., the residual liquid made up to 100 c.c., and the ammonia and nitrous acid determined.

	Taken.	Found.
Ammonical Nitrogen - -	·000192	·000166
Nitrous Nitrogen - -	·000172	·000142

The above figures prove that when a very dilute solution of ammonium nitrite is boiled, either in a glass or a platinum vessel, comparatively little of the nitrite is lost, either through oxidation to nitrate or through the breaking up of the nitrite into nitrogen and water.

APPENDIX 5.

Experiments showing the loss of Nitrous Nitrogen which may occur when effluents are boiled down for Nitrate Estimation, unless sufficient fixed base is present.

Method.—In the first set of two experiments an effluent from Caterham Barracks (No. 41) was used, and in the second set of seven experiments an "artificial effluent", made from solutions of potassium nitrite, potassium nitrate, ammonium carbonate and ammonium chloride of known strengths. In this second set the ammoniacal nitrogen in the ammonium chloride added was about 3·0 parts per 100,000 (limit of error, say, 0·1 part either way); this gives the chlorine as about 7·5 parts per 100,000. The total ammoniacal nitrogen was about 6·0 parts per 100,000.

The nitrous nitrogen having first been estimated in the original liquid, a known volume of the latter, diluted to about 150 c.c., was boiled down as usual to about 20 to 30 c.c., and the residual liquid was made up to a given volume with distilled water. An estimation of nitrite in one portion of this diluted residue gave, *by difference*, the loss of nitrous nitrogen that had occurred in the boiling down. In a second portion of the residue the nitric + nitrous nitrogen together were estimated by the copper-zinc couple method, and this result was compared with the corresponding "couple" estimation in the unboiled liquid, the difference between the two representing the total loss of oxidized nitrogen in the boiling down. The small difference between (a) the total loss of oxidized nitrogen and (b) the loss of nitrous nitrogen alone is due either to a slight loss of nitric nitrogen or to error of experiment.

The experiments with the Caterham effluent were less satisfactory than those with the artificial solutions, because in the former the amount of ammonia was relatively larger as compared with that of the nitrite :—

APPENDIX 5—(*continued*).

Date.	Volume of effluent taken (c.c.).	Nitrous Nitrogen taken (grms.).	Nitrous Nitrogen taken (parts per 100,000).	Nitrous Nitrogen in residue (grms.).	Nitrous Nitrogen in residue (parts per 100,000).	Loss of Nitrous Nitrogen (grms.).	Loss of Nitrous Nitrogen (parts per 100,000).	Total Oxidized Nitrogen taken (grms.).	Total Oxidized Nitrogen taken (parts per 100,000).	Total Oxidized Nitrogen in Residue (grms.).	Total Oxidized Nitrogen in Residue (parts per 100,000).	Total loss of Nitrogen (parts per 100,000).	Loss of Nitric Nitrogen (?) (grms.).	Loss of Nitric Nitrogen (?) (parts per 100,000).
July 29th, 1902	20		0·59		0·23		0·35		8·40		8·57	−0·17		−0·40
Aug. 1st, 1902*	20		1·09		0·60		0·49		9·63		9·06	0·58		0·09
Sept. 18th, 1902	25	0·000272	1·09	0·000195	0·78	0·000076	0·30	0·00162	6·46	0·00152	6·08	0·38	0·000019	0·08
,, 18th, ,,	25	0·000272	1·09	0·000220	0·88	0·000052	0·21	0·00162	6·46	0·00160	6·40	0·06	0·000034	0·15
,, 18th, ,,	25	0·000272	1·09	0·000220	0·88	0·000052	0·21	0·00162	6·46	0·00158	6·32	0·14	0·000016	0·07
,, 22nd, ,,	25	0·000272	1·09	0·000196	0·78	0·000076	0·30	0·00162	6·46	0·00153	6·10	0·36	0·000014	0·06
,, 22nd, ,,	25	0·000272	1·09	0·000209	0·83	0·000063	0·25	0·00162	6·46	0·00154	6·16	0·30	0·000011	0·04
,, 23rd, ,,	25	0·000272	1·09	0·000211	0·84	0·000061	0·24	0·00162	6·46	0·00154	6·15	0·31	0·000017	0·07
,, 23rd, ,,	25	0·000272	1·09	0·000206	0·83	0·000066	0·26	0·00162	6·46	0·00155	6·20	0·26	0·000002	0·01

* The experiment of August 1st was done with the same Caterham effluent as was used on July 29th, but with the addition of some potassium nitrite

APPENDIX 6.

Experiments made in order to see whether any loss of Nitric Nitrogen takes place when Solutions containing Ammonia, Nitrate and Chloride, in Quantities similar to those found in Effluents from Strong Sewages, are Evaporated to a small Volume.

Method.—The solutions employed were Potassium Nitrate, Ammonium Carbonate, Ammonium Chloride and Sodium Chloride. After these had been mixed in the required proportions for an experiment, the solution was made up to 150 c.c. with distilled water (this being the usual volume when making estimations of nitrate in effluents containing large quantities of ammonia), and boiled down to about 18 c.c. in a small Jena flask over a rose burner. When cool, the liquid was made up to a given volume with distilled water, and a suitable portion was taken for the estimation of nitrate by the copper-zinc couple method, the usual "blank" experiment being, of course, carried out concurrently. A small amount of nitrate, present in the reagents other than the potassium nitrate, which amounted only to a correction of 0·3 c.c. Ammonium Chloride in 39·5 c.c., was determined and allowed for in the results tabulated on the following page :—

APPENDIX 6—*continued.*

Date.	Volume of artificial effluent taken (c.c.).	Ammoniacal Nitrogen taken (Grms.).	Ammoniacal Nitrogen taken, in parts per 100,000.	Chlorine taken (Grms.).	Chlorine taken, in parts per 100,000.	Nitric Nitrogen taken (Grms.).	Nitric Nitrogen taken, in parts per 100,000.	Nitric Nitrogen found (Grms.).	Nitric Nitrogen found, in parts per 100,000.	Loss of Nitric Nitrogen. (Grms.).	Loss of Nitric Nitrogen, in parts per 100,000.	Loss of Nitric Nitrogen, Per cent.
October 1st, 1902 - -	25	0·00151	6·04	0·003176	12·7	0·00134	5·36	0·001334	5·34	0·000006	0·02	0·45
October 1st, 1902 - -	25	0·00151	6 04	0·003176	12·7	0·00134	5·36	0·001310	5·24	0·000030	0·12	2·24
October 2nd, 1902 - -	25	0·00151	6·04	0·003176	12.7	0·00134	5·36	0·001334	5·34	0·000006	0·02	0·45
October 2nd, 1902 - -	25	0·00151	6·04	0·003176	12·7	0·00134	5·36	0·001310	5·24	0·000030	0·12	2·24
October 3rd, 1902 - -	25	0·000755	3·02	0·002197	8·8	0·000268	1·07	0·000261	1·04	0·0000075	0·03	2·80
October 3rd, 1902 - -	25	0·000755	3·02	0·002197	8·8	0·000268	1·07	0·000263	1·05	0·000005	0·02	1·86
												1·67 % = Mean loss.

The chlorine as estimated in the residues agreed substantially with the original quantities taken.

APPENDIX 7.

(1) Testing Manganese Mud from Kjeldahl Potash Residues for Nitrogen.

A quantity of this mud was washed with water two or three times by decantation, but there was still a very appreciable quantity of alkali left in it. 16·55 grms. of the wet mud *, with all the supernatant water possible pipetted off, were then subjected to the Kjeldahl process. The ammonia ultimately found required for neutralisation 0·25 c.c. of (approx.) $\frac{N}{10}$ acid. But the "blank" required 0·30 c.c.

There was thus no Nitrogen in the Manganese Mud.

(2) Some Blank Kjeldahl Estimations, including a few with Zinc Dust.

Estimations 1 to 6 were made with reagents which were not purified. Estimations 7 and 8 were made with reagents purified as stated (excepting that at this time the sugar solution was not previously boiled up with potash, and fragments of zinc were used in the final distillation).

In every case 100 c.c. distilled water was used as the liquid.

The results are stated in fractions of a c.c. of approximately decinormal acid.

(1) 10 c.c. sulphuric acid (not "Nitrogen free") + potash (about 35 grms. of 75 °/₀ KOH).

November 8th, 1898 - - - 0·20 c.c. acid.

March 7th, 1899 - - - 0·20 c.c. ,,

(2) 10 c.c. sulphuric acid (not "Nitrogen free") + 10 grm. Na_2SO_4, 10 Aq + potash.

November 17th, 1898 - - 0·26 c.c. acid.

January 24th, 1899 - - - 0·29 c.c. ,,

(3) 10 c.c. sulphuric acid (not "Nitrogen free") + 10 grm. Na_2SO_4, 10 Aq + 0·2 grm. sugar + potash.

December 19th, 1898 - - 0·44 c.c. acid.

(4) 10 c.c. sulphuric acid (not "Nitrogen free") + 10 grms. Na_2SO_4, 10 Aq. + 2 grms. zinc + 0·2 grm. sugar + potash.

January 16th, 1899 - 0·60 c.c. acid, equal to ·00092 grm. N_2.

January 19th, 1899 - 0·54 ,,

March 8th, 1899 - - 0·54 ,,

---

* Note.—The mud was fairly thick, but the water in it was not estimated.

APPENDIX 7.—*continued.*

(5) 10 c.c. sulphuric acid (not "Nitrogen free") + 10 grms. Na_2SO_4, 10 Aq. + about 2 grms. zinc dust + 2 grms. salicylic acid + potash.

December 7th, 1898 - - -	0·88 c.c. acid.
December 15th, 1898 - -	0·89 c.c. ,,
December 22nd, 1898 - -	0·98 c.c. ,,

(6) 10 c.c. sulphuric acid (not "Nitrogen free") + 10 grms. Na_2SO_4, 10 Aq. + 2 grms. zinc dust + 0·2 grm. sugar + potash.

December 20th, 1898 - -	0·96 c.c. acid.

(7) 10 c.c. "Nitrogen free" sulphuric acid + 10 grm. Na_2SO_4, 10 Aq. + potash boiled out with permanganate.

May 6th, 1899 - - - -	0·23 c.c. acid.
May 8th, 1899 - - - -	0·235 c.c. ,,

Two different solutions of potash were used in these last two estimations. This blank is equal to 0·00031 grm. Nitrogen.

(8) 10 c.c. sulphuric acid + 10 grms. Na_2SO_4, 10 Aq. + 2 grms. zinc + 0·2 grm. sugar + potash boiled out with permanganate.

May 2nd, 1899 - - - -	0·21 c.c. acid.
May 9th, 1899 - - - -	0·22 c.c. ,

Some later estimations are higher than this (0·3 to 0·4 c c.)

APPENDIX 8.

Is there any quantitative relation between the Albuminoid Ammonia found, the Alkaline Permanganate reduced during the production of this Albuminoid Ammonia at boiling temperature, and the "Oxygen absorbed" from Acid Permanganate in 4 hours at 26·7°C. (80°F.)?

Three preliminary experiments have been made with the object of gaining some light upon the above question. Being so few in number, they of course require to be added to, but the method followed may be shortly detailed :—

From 700 c.c. of distilled water 200 c.c. were distilled off, and to the residual 500 c.c. in the retort there was added sewage, tank liquor or effluent in such quantity as to give a reasonable amount of albuminoid ammonia (the actual limits were 0·00005 to 0·00014 grm. albuminoid nitrogen). The free ammonia was of course distilled off before the addition of the 15 c.c. of alkaline permanganate used for the albuminoid ammonia estimation, the exact value of this permanganate having been previously determined by potassium iodide and thiosulphate. At the end of the distillation the residual liquor was cooled and made up to a definite volume, and a convenient portion of it was titrated with thiosulphate. From these initial and final strengths the amount of permanganate used up during the distillation was arrived at; the albuminoid ammonia was nesslerized in the usual way. Concurrently with the above, a determination of "Oxygen absorbed" from acid permanganate in 4 hours at 80°F. was also made.

The following table gives the results which have so far been obtained :—

Date.	Nature of Sample.	Parts per 100,000 by weight.		
		Albuminoid Nitrogen.	Oxygen absorbed from Alkaline Permanganate in the Albuminoid Ammonia determination.	Oxygen absorbed from Acid Permanganate in 4 hours at 80° F.
Jan. 21st, 1903.	Mixed effluent and Settled Sewage from Halton - -	0·29	8·28	3·02
Jan 23rd, 1903.	Ealing Crude Sewage filtered through glass wool - -	0·74	38·20	13·98
Jan. 27th, 1903.	General effluent from Aldershot Camp Farm, drawn Sept. 8th, 1902 - -	0·10	4·85	2·40

With so few data it would be useless to attempt any generalisation, excepting that the "oxygen absorption" figures from alkaline and acid permanganate follow one another fairly well. We hope to make some further estimations of this kind, if time permits.

WELLCOME LIBRARY INSTITUTE